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SHEET IRON

A PRIMER



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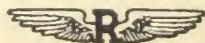
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SHEET IRON

A PRIMER

Foreword

ONE of the most powerful factors in the progress of civilization has been the development of the sheet metal industry. So extensive are the applications of sheet metal today that there is scarcely a moment in our lives when we are not affected by it in some form or other. The industry has become one of the wonders of the modern world. Huge manufacturing organizations employing thousands of men in far-flung plants valued at hundreds of millions of dollars, produce sheet metal of all descriptions to increase our comfort, safety and happiness.

Schools and colleges have added practical courses in sheet metal working to help fit young men for the various phases of the sheet metal fabricating business. It is chiefly in answer to requests from hundreds of these schools for information on sheet iron manufacturing that this and earlier editions of the Primer have been published. The present edition has been revised to take account of recent developments in sheet metal manufacturing and of metallurgical changes which have been made as a part of our continual effort to increase sheet iron durability and usefulness.

It is hoped that every reader will find the Primer of interest and use. Should additional information be required on any subject treated in the Primer, please consider this a cordial invitation to write for it. All letters should be addressed to Republic Steel Corporation, Dept. 127, Massillon, Ohio.

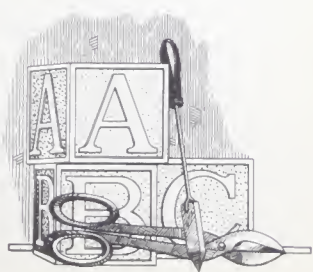


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THE IMPORTANCE OF IRON

CHAPTER I

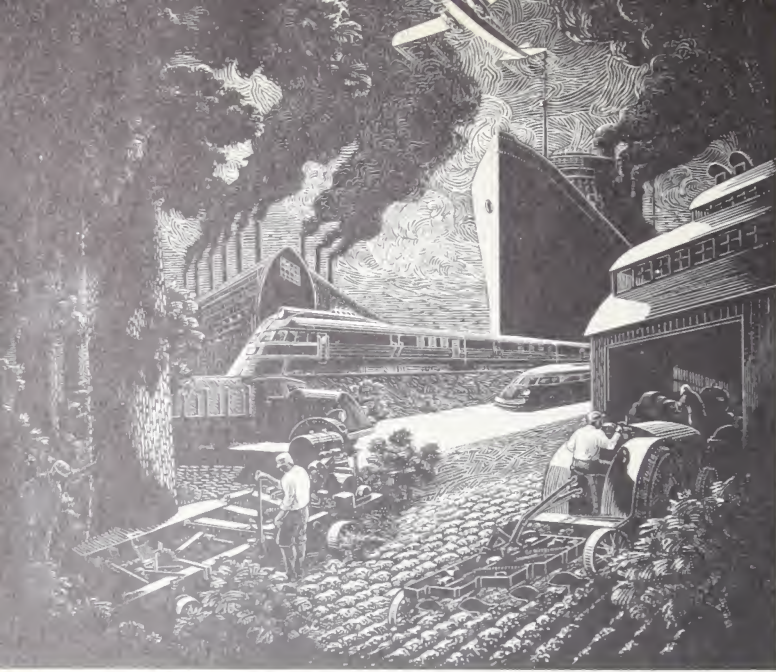
IRON is the most useful of all metals. Without iron, the world could not have advanced from savagery to civilization. The precious metals, gold and silver, are far more costly than iron because their supply is relatively limited. They are used chiefly for coinage purposes, although lesser quantities are used for jewelry and for medical and dental work.

We pay as much for an ounce of gold as we do for many hundreds of pounds of iron. Nevertheless, it is not enough to compare only the intrinsic values of gold and iron. A few moments of thought reveal that progress in civilization has become dependent upon our ability to smelt iron from its ore and to refine and shape it into useful products.

The houses in which we live, the schools wherein we study and the buildings in which we work owe their very existence to iron in the form of various building materials. The automobile, the airplane, the railroad train, the ocean liner—none of these would have been possible without the aid of iron. The toys of play, the tools of work and the weapons of war have made iron of supreme importance. And so on, almost indefinitely, we may cite our luxuries and our necessities in terms of iron . . . the most useful of metals in peace as well as in war.

Of all the 92 chemical elements which make up this world, iron ranks fourth in quantity. Only oxygen, silicon and aluminum are more abundant.

Iron is found in nearly all kinds of rock and soil. It is iron oxide mixed with the soil that gives it its brown or reddish color. It dissolves in water and is taken up and used in producing plant color. It is also used by plants in the processes of living and growing. We find iron in the chlorophyll of plants and in the blood corpuscles of animals and human beings. Even the red cheeks of a child tell of the presence of iron. John Ruskin said of iron: "It breathes the air, burns itself up in oxygen, and so gives its own life that we may live."



*In peace as in war,
iron is the most use-
ful and most impor-
tant of all metals
known to mankind.*

Iron rarely occurs in Nature in free or uncombined forms. The meteorite of metallic iron is an exception. Iron usually occurs in the form of iron oxides. We call these oxides iron ore. Deposits of rock, shale and earth rich in iron ore are widely distributed over the earth's surface. Scientists estimate that as much as five per cent by weight of the earth's crust is made up of iron in combination with other elements.

Iron is the elder brother of steel. Steel, until recently, was defined as iron containing less carbon than cast iron (therefore not more than 2%) and more carbon than wrought iron. New irons and steels, containing little carbon and created for many special purposes in recent years, met this definition either with difficulty or not at all.

A few simple definitions which will prove helpful and interesting are as follows:

Cast Iron or Pig Iron: Iron containing so much carbon that it is not malleable (capable of being shaped by rolling, forging, etc.) at any temperature.

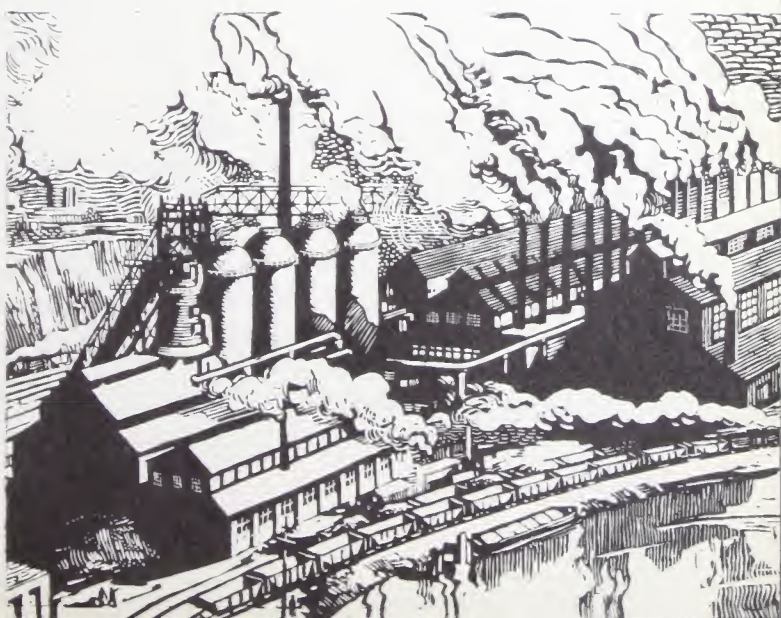
Malleable Cast Iron: Iron which when first made is not malleable but which is made malleable by subsequent treatment.

Wrought Iron: A slag-bearing refined iron, not hardenable.

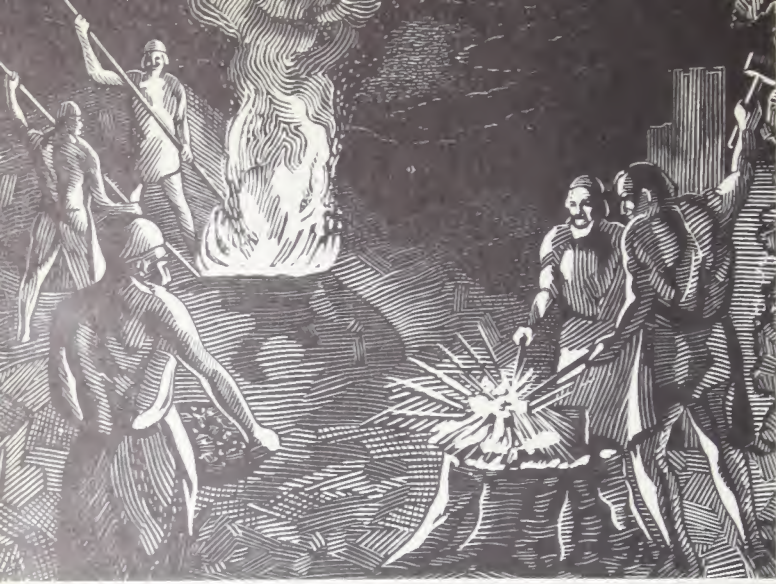
Steel: Iron which is malleable at least in a certain range of temperature (which distinguishes steel from cast iron and pig iron) and, in addition, is either (1) cast initially malleable (which distinguishes steel from malleable iron) and (2) hardenable (which distinguishes steel from wrought iron).

The following practical comparison between iron and steel is likewise useful: Impure iron is smelted from iron ore. The impure iron is refined and rolled into steel. The impure iron can be *highly* refined—beyond the steel stage—and rolled into an iron so pure as to contain less basic impurities than steel. This highly refined iron is more resistant than steel to their traditional enemies, rust and corrosion.

The term “ferrous material,” which will be used frequently, designates the element iron or any combination of elements of which the chief element is iron. The word “ferrous” comes from “ferrum,” the Latin word for iron.



The development of the iron and steel industry — one of the five largest industries — is the result of the ever-increasing use of these metals for many purposes.



In early days iron was made in hillside bloomeries where prevailing winds provided the draft.

THE EARLY HISTORY OF IRON

CHAPTER II

WHEN, where or how man first laid bare the secret of iron ore is not known. Imagine some prehistoric savage squatting before a fire which chance had led him to build over an outcropping of ore. Soon the blazing wood changes to charcoal. The charcoal fuses with the ore under the intense heat and produces metallic iron. The awe-struck savage beholds a lump of glowing metal, unlike anything he has ever seen before.

Or perhaps a lightning bolt started a forest fire which revealed in like manner the secret destined to change the story of the human race. Such accidental discoveries of iron doubtless happened in many places during the dim days of early time.

Biblical history and other records of early tribes and nations make frequent references to iron. The ancient civilizations of Egypt, India, Assyria, Persia, Rome and Greece owed much of their growth and power to iron.

Little progress in the manufacture of iron was made for several centuries after the beginning of the Christian era. But in the eighth

century iron-making took a fresh start. The forging of swords and of armor became an industry of vast importance. The smiths who produced iron became persons of high political and social rank whose favor was sought by kings and nobles. The fame of Damascus swords, Moorish armor and Italian mail still lives in song and story.

The forges of this period showed slight improvement, however, over those of much earlier times. They could not develop sufficient heat to melt the iron into liquid form. Charcoal was used to reduce the ore to a pasty mass of red-hot metal. To refine and shape the metal for use required long and repeated hammerings and heatings. Two men could produce scarcely a dozen pounds of iron in a day.

The invention of the blast furnace in Germany in the 15th century gave the world cast iron. Mills began to produce iron and steel, somewhat as we know them, in large tonnage. In the 18th century coke replaced charcoal in iron-making. This change made possible the development of the modern types of furnaces.

Sheet iron rolling began in England in 1728. Cast iron cylinders or rolls were used. The rolling mill did away with an immense amount of severe physical labor. Before its coming, sheets were made from pieces of wrought iron, heated at the forges of the smiths. They were hammered as flat and thin as possible on anvils. Several pieces were then piled together. They were re-heated and hammered until the combined layers had reached the desired thickness.



A blast furnace in New England built by the Pilgrims. It could produce only a few tons of iron a week.

Thus century after century, the development of iron advanced among the more progressive nations. Much of the iron was of high quality. The charcoal iron of English iron-masters of recent centuries is an example.

This iron was not ductile and easy to work, like the sheet iron of today. Sheet iron of that day was used for so few purposes, as compared with our own century, that these qualities were thought relatively unimportant. Iron was also costly. Hence, durability was the first consideration.

The reputation of English charcoal iron was built chiefly upon its ability to withstand many years of service. Atmospheric conditions, it is true, such as now result from the clouds of coal smoke always present in industrial communities, were much less severe in former centuries when wood was the principal fuel. And yet, there is no doubt but that the skilled, if far slower, production methods of the English iron workers developed an iron of unusually high quality.

In America iron ore was discovered in South Carolina in 1585 by an expedition sent from England by Sir Walter Raleigh. The first iron works was built in 1619 near Jamestown, Va. The iron mills of the colonists contributed much to the success of the Revolution. The first sheet rolling mill was erected in 1818 at Pittsburgh—a forerunner of the development which has made the Pittsburgh district the world's greatest center of iron and steel.

The inventions of the Bessemer and Open Hearth processes of steel-making about the middle of the past century caused giant strides in the industry. The United States quickly won a commanding place in the new period of high tonnage production. By 1880 British production of iron and steel was surpassed and the United States took rank as the world's largest iron-producing nation. Pennsylvania, Ohio, Alabama, Illinois and New York are the leading states in production.

In practically every country in the world enormous tonnages—little dreamed of only a generation ago—of molten iron and steel are being poured from furnaces and ultimately converted into finished ferrous products—metallic slaves of mankind. We call this era "The Age of Steel."

IRON ORE

CHAPTER III

IRON ore is a reddish-brown mineral found both in granular and rock-like formations. Near steel plants and near the docks of many cities along the Great Lakes may be seen mountain-like piles of what appears to be merely soft, red earth. It is iron ore.

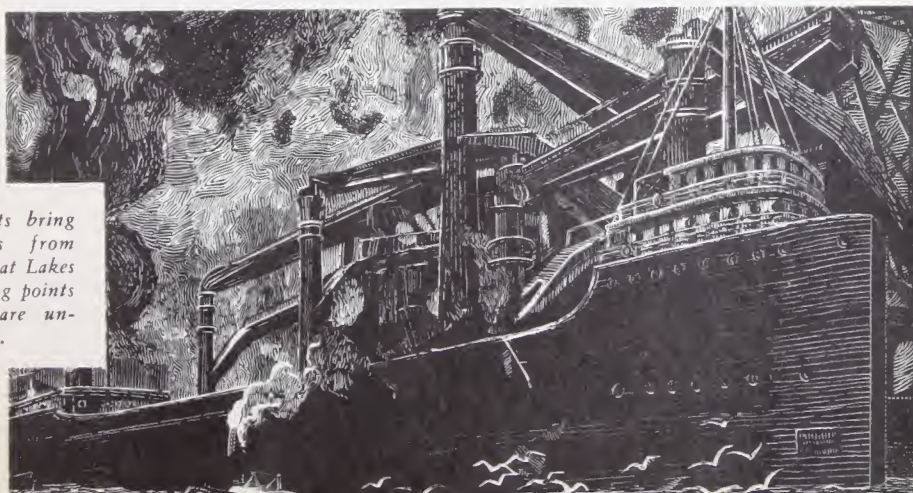
The bulk of our commercial iron is produced from four ores. They are the oxides known as hematite, magnetite, and limonite, and a carbonate called siderite. Of these, hematite is the most widely distributed and important ore.

A rich ore contains more than 50 per cent of iron; an average ore, from 35 to 50 per cent; a poor one, workable under favorable conditions, from 25 to 35 per cent. Ores containing less than 25 per cent of iron are at present considered useless.

The ore is mined in 28 of the American States, as well as in many other parts of the world. For several decades the most valuable ore bodies in America have been those of the Lake Superior district. Michigan, Wisconsin and Minnesota are the states which contain this large source of natural wealth. The Mesabi range in Minnesota yields more ore than any other in the world, or about four-fifths of this country's entire output. Nearly 100 miles long, it extends in an east and west direction about 50 miles northwest of Duluth.

The ore of the Lake Superior district lies near the surface of the ground. It can be mined cheaply with steam shovels. In less favored districts shafts must be sunk and the ore brought to the surface by elevators. Huge boats transport the ore to ports along the lower Great Lakes. Soon it reaches the great blast furnaces the country over.

Iron ore boats bring their cargoes from the upper Great Lakes to rail shipping points where they are unloaded.



COKE is made by the heating of coal to a high temperature in the absence of air. The volatile impurities of the coal are burned off and the fixed carbon and ash are left behind. As the volatile combustible impurities of the coal would seriously contaminate the iron during the smelting operation in the blast furnace, it is essential that they be expelled. The residual carbon and ash are in the form of a porous cellular material. Because coke is porous (1) it allows penetration by air, resulting in rapid combustion and (2) it has a high load-bearing strength which enables it to carry the weight of the heavy charge in the blast furnace without crumbling or packing.

Coke is made by two methods. In the older method, it is made in a "bee-hive" oven, a dome-shaped brick structure. The volatile matter is allowed to escape and is therefore wasted. In a relatively newer method, the by-product process, the volatile matter is converted into useful products.

Bee-hive ovens are located at the coal mines. This necessitates the coking of the one grade of coal received from that mine. In the by-product process, however, the ovens are built at the steel works. The operator therefore has a choice of coals, enabling him to make coke from a combination of different grades of coal and thus to improve the quality of the coke produced.

At the finish of the coking process the coke is quenched under a water spray, dried, and then screened into various sizes. One size of coke is consumed at the blast furnace. Another size is sold for domestic fuel. Finally, all coke that passes through the $\frac{7}{8}$ " screen is called "breeze" coke and is used for boiler fuel in the power house.

From every ton of coal the following approximate quantities of coke in terms of percentage by weight of the original ton of coal, and of by-products are obtained:

65% Furnace Coke, size $3\frac{1}{4}''$ to $1\frac{1}{2}''$.

5% Domestic Coke, size $1\frac{1}{2}''$ to $\frac{7}{8}''$.

5% Breeze Coke, size under $\frac{7}{8}''$.

26 to 27 lbs. ammonium sulphate, used for fertilizer.

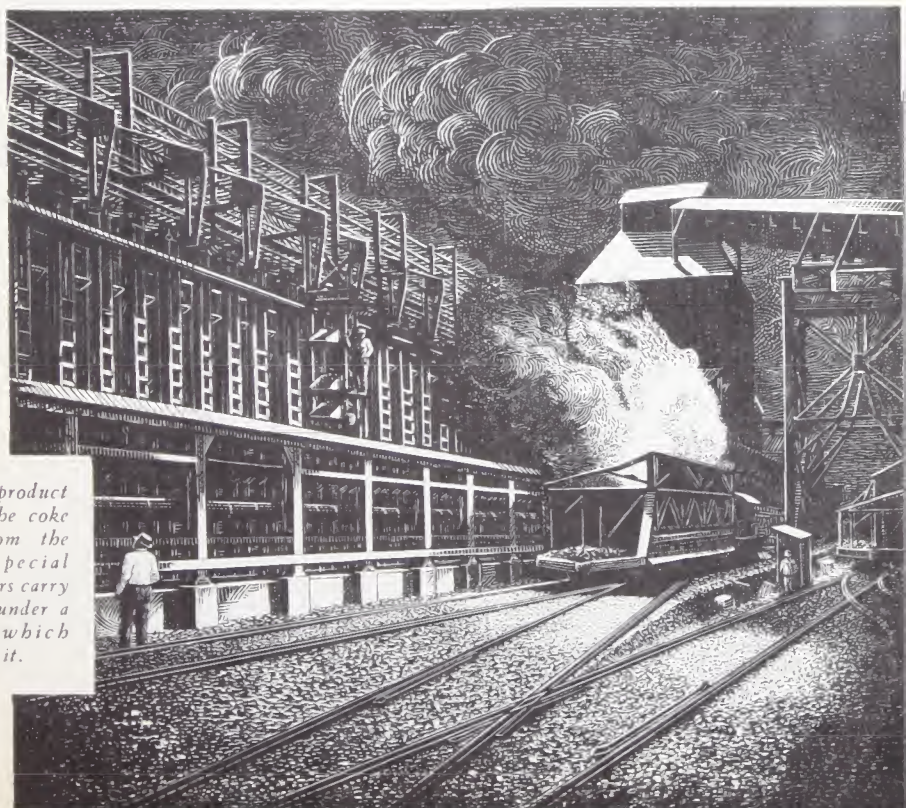
11 to 12 gallons tar, sold to tar refineries.

1.5 to 1.7 gallons benzol, used in chemical industries and as a blend for gasoline.

.5 to .7 gallon toluol, which is the basis of munitions manufacture and is used at present in the manufacture of lacquers.

.3 to .5 gallon solvent naphtha, used in the manufacture of varnishes.

10,000 cu. ft. gas, 35% of which is used for heating the coke ovens and the balance available as fuel for the steel plant.



In modern by-product coke plants, the coke is pushed from the ovens into special cars. These cars carry the hot coke under a water spray which quenches it.

THE BLAST FURNACE

CHAPTER V

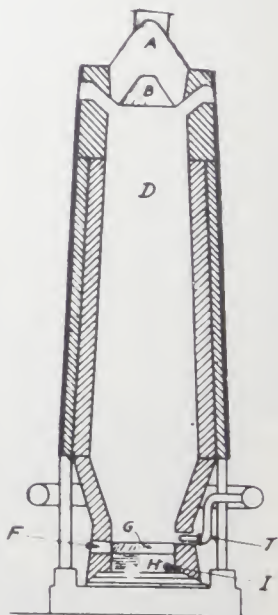
ALL IRON ORE as it comes from the mines contains earthy matter and other impurities. The blast furnace is the first step in the actual conversion of the ore to iron and steel.

The blast furnace does three important things. (1) It separates the earthy matter and much of the other impurities from the ore. (2) It releases the iron from the oxygen with which it is combined. (3) It adds the carbon which the soft iron requires to give it stiffness.

The blast furnace is a huge steel shell or tower, sometimes more than 100 feet tall. It is lined with fire brick. Let us take, for example, a furnace of average size, such as the one at the Canton, Ohio, plant of Republic Steel Corporation. It is ninety feet high. It widens from the bottom to a diameter of 22 feet and then tapers again toward the top. Near the bottom, pipes called tuyeres admit the forced draft, or air "blast," which gives the furnace its name.

Diagram of
Blast Furnace

The charge consisting of ore, coke, and limestone is loaded into the hopper "A" and dumped into the shaft "D" by lowering the bell "B." The air blast enters through the tuyeres "T." The hot coke takes the oxygen from the ore, leaving molten iron which drops down and collects in the hearth "H" and is tapped out through the "Iron Notch" "I." The limestone fuses with dirt in the ore and the ash of the coke to form slag "G" which floats on the iron and is tapped through the cinder notch "F."



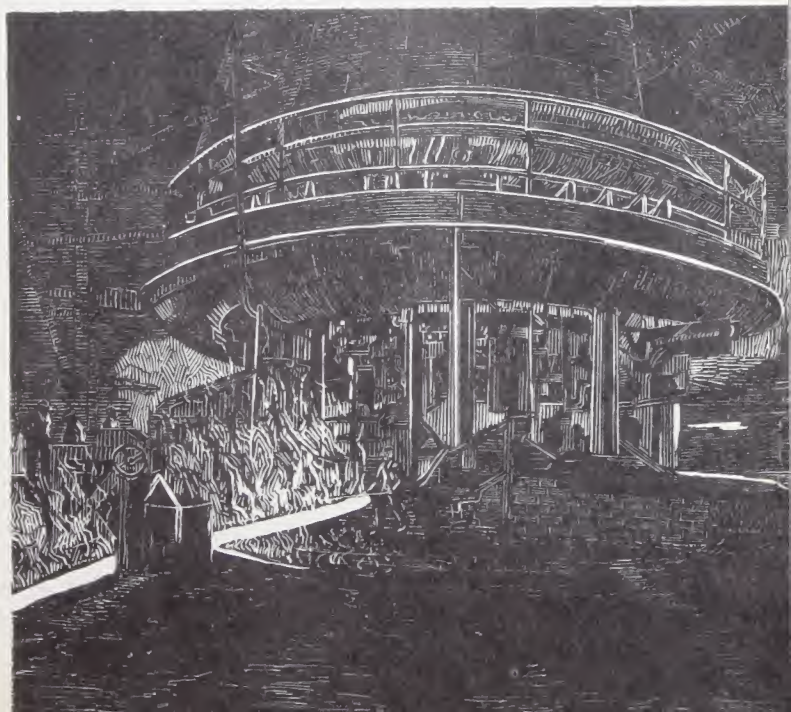
The furnace is equipped with three steel tanks or stoves, cylindrical in shape. Each is 110 feet high and 24 feet in diameter. Their purpose is to supply heated air for the furnace. A central flue opens into a chamber on top, in each stove. From this chamber channels lead through fire brick to another chamber at the bottom.

Blast furnace gases enter the central flue, are burned with air, rise and pass down through the side channels to heat the fire brick. At the bottom they discharge through a chimney. Then dampers close the chimney and shut off the gas, while air is pumped through the same channels by powerful engines. Heated in the side channels, the air finally passes down the central flue and enters the bottom of the furnace. Meanwhile the gases from the furnace are heating another stove.

The furnace is charged from the top by huge buckets operating on an inclined track. The buckets keep the furnace filled with successive layers of iron ore, limestone and coke. The furnace works day and night, seven days a week, save when a shut-down is necessitated.

The blazing gas fire of the furnace, intensified by blasts of hot air from the stoves to temperatures of 2,800 to 3,000 degrees Fahrenheit,

*Tapping a heat of
fiery metal from the
huge blast furnace at
Republic's Massillon,
Ohio, plant.*



reduces the ore first to a spongy mass and then to a liquid state. The calcium of the limestone, acting as a flux, combines with the earthy matter and most of the other impurities to form a glossy scum called slag. Coke frees the molten iron from the oxygen of the ore. The oxygen combines with the carbon of the fuel and passes off as carbon dioxide gas.

As the iron is reduced it trickles over the hot coke below, absorbs carbon and drops to the hearth, or bottom of the furnace, like fat frying out of a roast. The slag, lighter in weight, swims on the surface of the iron.

Periodically, about every four hours, the molten iron and slag are tapped out of the hearth into separate ladles. A "heat" ranging from 80 to 120 tons of iron, flows out in a fiery, hissing stream into 75-ton mixer ladles that are soon carried to the refining furnaces.

The average daily tonnage of the furnace we have just described was 725 tons during a recent month's operation.

For every ton of iron produced in the blast furnace, approximately 2 tons of ore, 1 ton of coke, $\frac{1}{2}$ ton of limestone and 4 tons of air are used. These materials are converted into $\frac{1}{2}$ ton of slag and 6 tons of gases, in addition to the 1 ton of iron.

IN OLD-FASHIONED blast furnaces the molten iron was drawn off directly into sand molds or troughs. These bore a fancied resemblance to a litter of pigs lying alongside their mother and feeding. Hence the term "pig iron" was applied to the product of the blast furnace.

In modern practice the liquid iron is rushed to the iron and steel mill for immediate refining. Or it may go to the "pig" casting machine which has taken the place of the old sand molds. "Pigs" permit convenient storage or shipment of the iron.

Whether or not it ever becomes a "pig," the product of the blast furnace is called "pig iron." It is the intermediate or semi-raw material from which practically all ferrous materials of whatever kind—cast iron, wrought iron, alloy iron, sheet iron or steel—are made.

Solid pig iron may be remelted in a cupola and cast into gray or white iron castings. Solid pig iron is also remelted and purified in a puddling furnace into mechanically puddled wrought iron. Liquid pig iron is charged into a Bessemer converter and quickly refined to Bessemer steel. Either or both liquid and solid pig iron are mixed with steel scrap and made into alloyed or unalloyed steel and iron by the open hearth or electric furnace process.

Pig iron contains a sufficiently large proportion of natural impurities—manganese, sulphur, phosphorus and silicon—to make the iron weak and brittle. It must be refined before it is fit for commercial use.

The analysis of pig iron varies considerably, depending on furnace conditions and the raw materials used. The following analysis is representative:

Carbon	3.50%
Manganese	2.00%
Sulphur .....	.04%
Phosphorus .....	.30%
Silicon	1.25%

THE BESSEMER PROCESS

CHAPTER VII

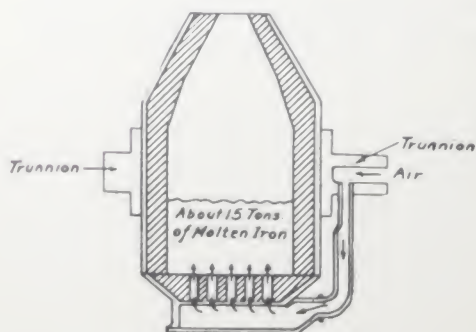
ABOUT 1847 an American named William Kelly noticed that a draft of air striking molten iron in his Kentucky iron works made the metal seethe and boil.

Why did cold air heat instead of chill the metal? He remembered that the molten iron still contained carbon and other combustible material. He guessed that the oxygen of the air captured and carried away the excess carbon. In other words, it boiled by burning its own fuel.

This was the beginning of modern methods of refining pig iron and of making steel. A few years later Sir Henry Bessemer of England observed the same thing. He worked out the "fuel-less" process which he patented in Great Britain in 1855.

Bessemer reaped most of the fame from the discovery, but Kelly was granted a patent in the United States. It is now generally agreed that the two inventors stumbled on the same discovery. The product of the so-called Bessemer process is Bessemer steel.

The Bessemer process uses a large pear-shaped vessel or converter. It is made of steel plates and lined with fire brick. It is so mounted that it can be rotated for pouring. Through many small holes in the bottom of the converter air is forced by great pressure into the molten charge of pig iron. A single charge weighs about 15 tons. The pressure of the air blast is sufficient to prevent the molten metal from entering the air nozzles.



**Diagram of
Bessemer Converter**

The converter is rotated on the trunnions "T" to the horizontal position and partly filled with molten pig iron. It is then turned back to the vertical position and the air blast turned on. The air enters through the holes in the bottom and is forced through the molten pig and burns out the impurities in a few minutes. The converter is then turned forward and the charge is poured into the ladle.

The air blast burns out or oxidizes a large portion of the impurities remaining in the pig iron. They pass off in the form of gas in a burst of flames and a shower of sparks. Most of the solid impurities, such as the oxides of manganese and silicon, rise to the surface of the metal as slag.

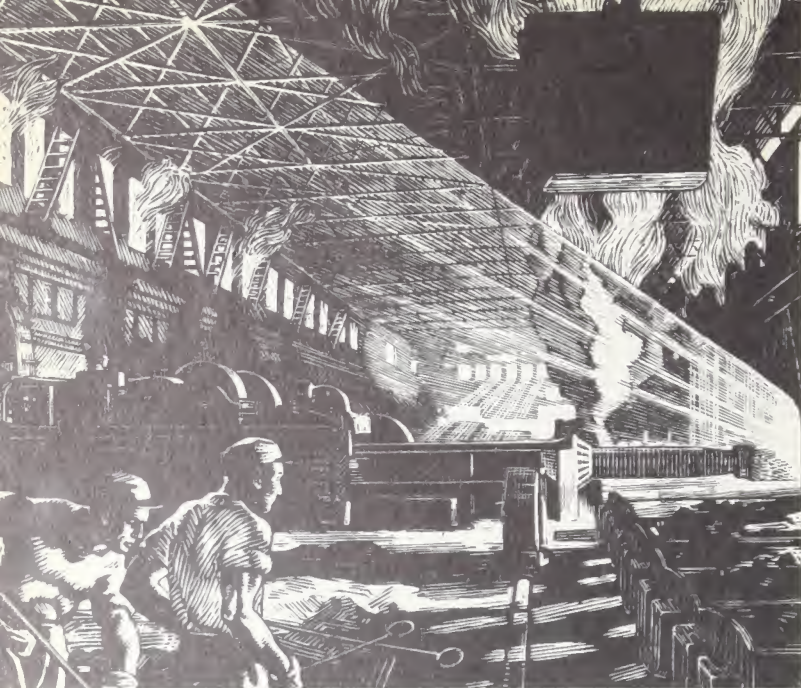
The process requires from 10 to 15 minutes. The color of the flames tells when the operation has been completed. Owing to the heat generated by the burning carbon and silicon, the temperature of the metal is higher at the end of the "blow" than at the beginning.

The Bessemer process produces a commercial steel that is suitable for rails and other construction materials. The Bessemer is a much cheaper method of production than the Open Hearth process. The latter method however produces a better quality of iron and steel. For this reason and also because of the growing scarcity of ores suitable for bessemerizing, three times as much iron and steel in the United States is made by the Open Hearth process as by the Bessemer.

There are also electrical processes of iron and steel making which have been in commercial use since the beginning of the 20th century. The product of electrical furnaces is quite expensive, however, and the bulk of the world's tonnage is made by the Bessemer and Open Hearth processes.



Tapping one of a battery of Republic's electric furnaces.



Large charging machines pick up metal boxes filled with materials for the charge and place the contents in the Open Hearth furnaces.

THE OPEN HEARTH PROCESS

CHAPTER VIII

SCARCELY a year after the granting of the first Bessemer patents came the first steps in the development of the Open Hearth process. In 1856 the Siemens brothers developed their gas producers in England. They patented the Siemens regenerative gas-fired furnace.

In 1864 Emile and Pierre Martin of the Sireuil Works in France erected, with the Siemens' aid, a Siemens furnace. It melted steel on an open hearth, or reverberatory. It produced cast steel of good quality and of various tempers.

Thus were laid the foundations of the Siemens-Martin Open Hearth process. It is now in general use for the production of the better grades of iron and steel. A slower but more thorough method, it differs greatly from the Bessemer process.

An open hearth furnace resembles a huge oven. Several furnaces usually are built together in a row. They are built of steel and refrac-

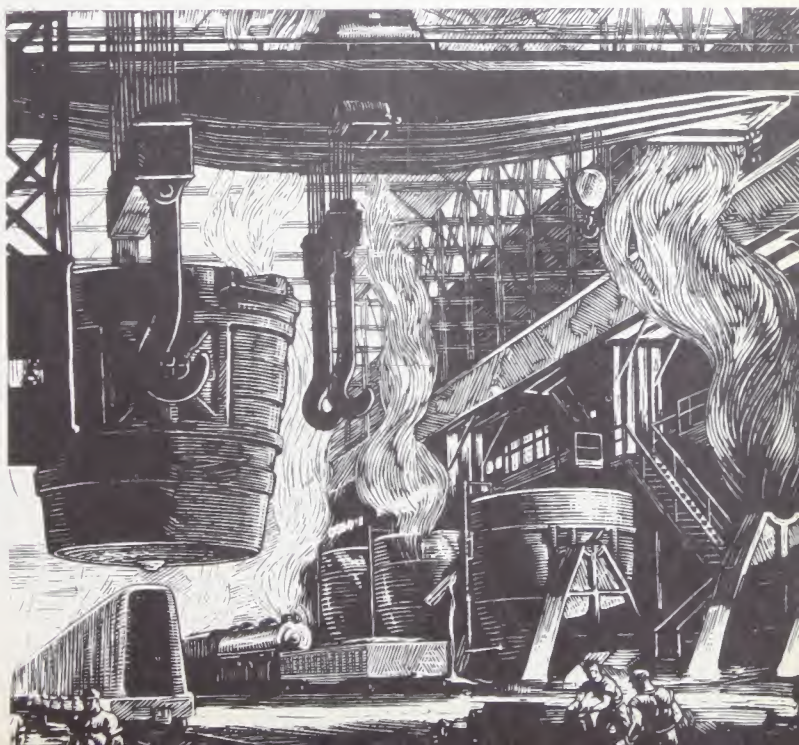
tory brick. In the average seventy-five-ton furnace, the hearth is 35 feet long, 13 feet wide and two feet deep.

The hearth is really a basin in which the refinement of the molten iron takes place. It is played over by intense heat but is shielded from the direct flames of the furnace. The greater heat required by the process is obtained by an ingenious device called the "regenerative furnace." For about half an hour gas and air enter through the "ports" or valves on one side, and burn in the furnace. The hot gas produced by the combustion escapes through the "ports" on the opposite side. Then the valves are reversed and the gas and air admitted through the heated chambers on that side. This periodic reversal produces a continually rising heat until the charge is ready to tap. It takes about 12 hours to make a 75-ton "heat."

First limestone and then scrap iron are dumped into the furnace by charging machines. A charge of pig iron follows. The heat from the blazing gas gradually reaches a temperature close to 3,000 degrees Fahrenheit to melt the charge.

The limestone, which has been burned to quicklime during the process, floats up through the molten metal and absorbs phosphorus,

The pouring side of an Open Hearth furnace. Tapping one of these furnaces is a spectacular sight.

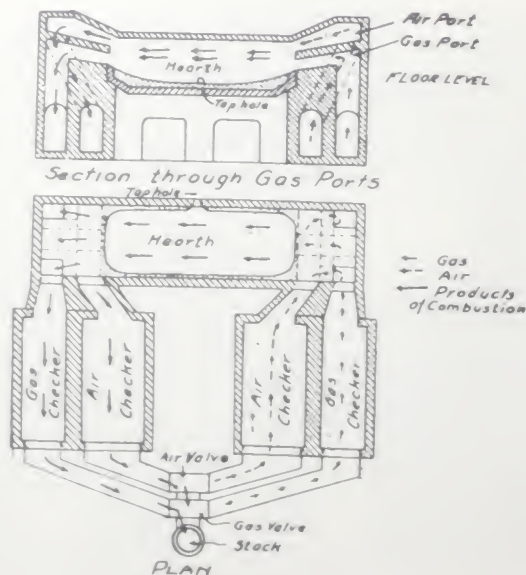


sulphur and other impurities. They form slag on the surface of the purified iron. Small quantities of the metal are dipped out for testing purposes. The appearance of a test block, when fractured, permits the furnace men to make a rough estimate of the analysis of the metal. The last few test blocks go to the laboratory for rapid analysis.

At length the desired analysis is obtained and the metal's temperature is right for casting. A tap hole at the rear of the furnace is opened. The iron flows out into a ladle. The fiery stream and the shower of sparks spattering up from it light up the dim vault of the building with a brilliant glare. The slag flows out last and over-runs the filled ladle.

This method of making steel is the basic Open Hearth process, as used by most of the steel plants in this country. It differs from the acid Open Hearth process in that the furnace linings and the flux material used in the operation possess basic instead of acid properties.

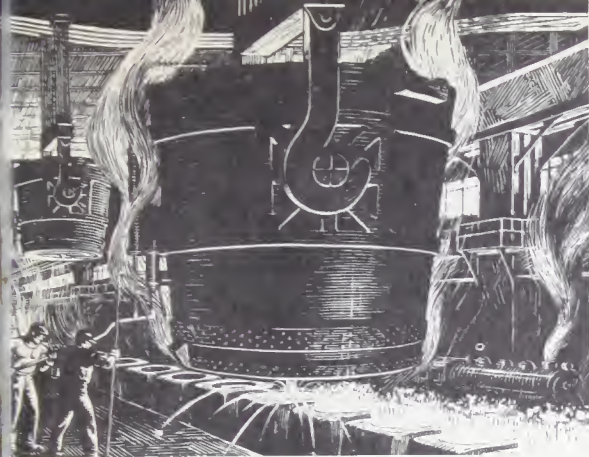
The character of the iron ore used and the chemical analysis desired for an Open Hearth iron or steel determine which of the two methods is proper for its production.



**Diagram of
Open Hearth
Furnace**

Arrows show direction of gases through the furnace when gas is on the right end. Direction is reversed when gas is on left end of furnace.

Limestone, scrap iron and pig are charged on the hearth. The charge is melted, and some of the impurities are burned out by the gas flame which passes over it. The lime forms a slag with other impurities. The furnace is reversible and equipped with checker chambers for pre-heating the gas and air.



*Pouring molten iron into
ingot molds in the Open
Hearth department.*

THE INGOT

CHAPTER IX

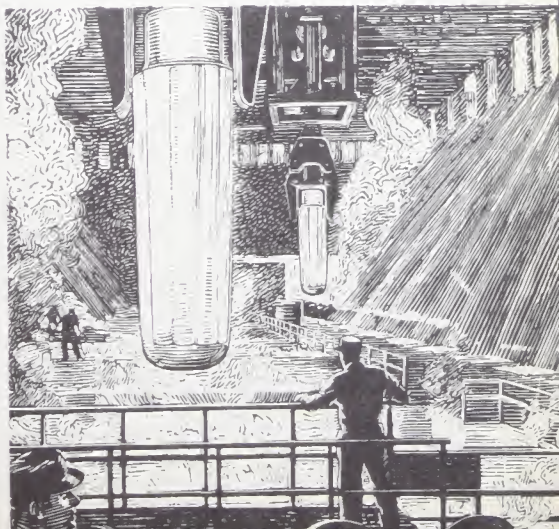
AFTER the metal has been refined by the Open Hearth or the Bessemer process, cranes operating on overhead rails carry the ladle with its molten load to a row of large cast iron molds. These are called ingot molds.

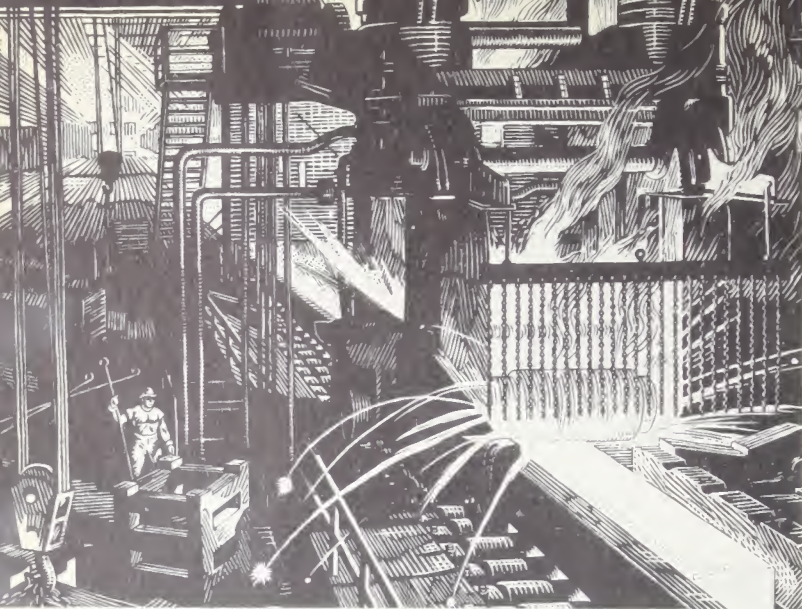
The white-hot metal fills the molds, cools and hardens into ingots. During the cooling process, gases and other impurities in the metal rise to the top of the ingot form. After the ingots have solidified, electrically operated strippers remove the molds. Ingots vary in weight, according to the sizes of the molds, from 1,000 to as much as 8,000 pounds.

The entire handling of the ingots is by machinery. Traveling cranes lift and carry them to the soaking pits. The pits are furnaces below the floor level. Into the pits the ingots are lowered to be reheated for rolling.

The reheating process is conducted with great care. The temperature from the center to the surface of each ingot must be uniform. Overheating of the surface will cause surface defects in the sheet bars, the rolling of which will be described later.

*Ingots are heated in the soaking pits
before they go to the blooming mill.*





*The blooming mill
changes an ingot into
the bloom.*

THE BLOOMING MILL

CHAPTER X

THE first working of the ingot comes in the blooming mill. Each mill includes a pair of heavy steel rolls. One roll is above the other, as in a clothes-wringer. Heavy steel housings support the rolls.

The mill's drive is so designed that the direction in which the rolls turn can be instantly reversed. The ingot can be passed either forward or backward between the rolls, as the operators may desire.

The mill's entire operation is controlled from an "operating pulpit" that resembles the bridge of a battleship. The "pulpit" is equipped with an ingenious set of control levers. These permit the operators to control the speed and direction of the driving motor, to regulate the distance between the rolls, and to operate a set of giant fingers or "manipulators." The fingers turn the ingot and shift it to any desired position in front of the rolls.

The red-hot ingot receives repeated turns as it passes forward and backward through the rolls. It becomes thoroughly worked on all sides. At the same time its width and thickness are reduced and its length increased, as the operator closes the gap between the rolls.

Within a few minutes the ingot has been converted into a semi-finished piece called a "bloom."

STILL very hot, the bloom is transferred mechanically from the blooming mill to the continuous sheet bar mill. On its way the bloom passes through a heavy cropping shear. The shear crops or cuts off the ends which formed the top and bottom of the ingot and which may contain segregated gases and impurities.

The bar mill consists of a number of stands or sets of rolls placed in a tandem arrangement. This allows the bloom to pass continuously from one stand to the next. The rolls of each stand are so adjusted that each bar decreases in width and thickness and increases in length as it passes through the successive sets of rolls. The final set of rolls gives the bar the desired gauge or foot-weight.

The sheet bar now travels on a table equipped with power-driven rollers through a flying shear or saw. This automatically cuts the bar into thirty-foot lengths.

The cut bars are stacked in piles and moved to cooling racks. Soon they are ready to be loaded in cars for delivery to the sheet rolling mill.



The bar mill transforms a bloom into a bar.



A battery of hot sheet rolling mills converting sheet bars into sheets.

THE SHEET ROLLING MILL

CHAPTER XII

LIKE the blooming mill, the sheet rolling mill also looks like an enormous clothes-wringer. The rolls are made of special chilled iron. They vary in width according to the size of the sheet to be rolled. They revolve constantly. The rolls of several mills are coupled together and are driven by an electric motor.

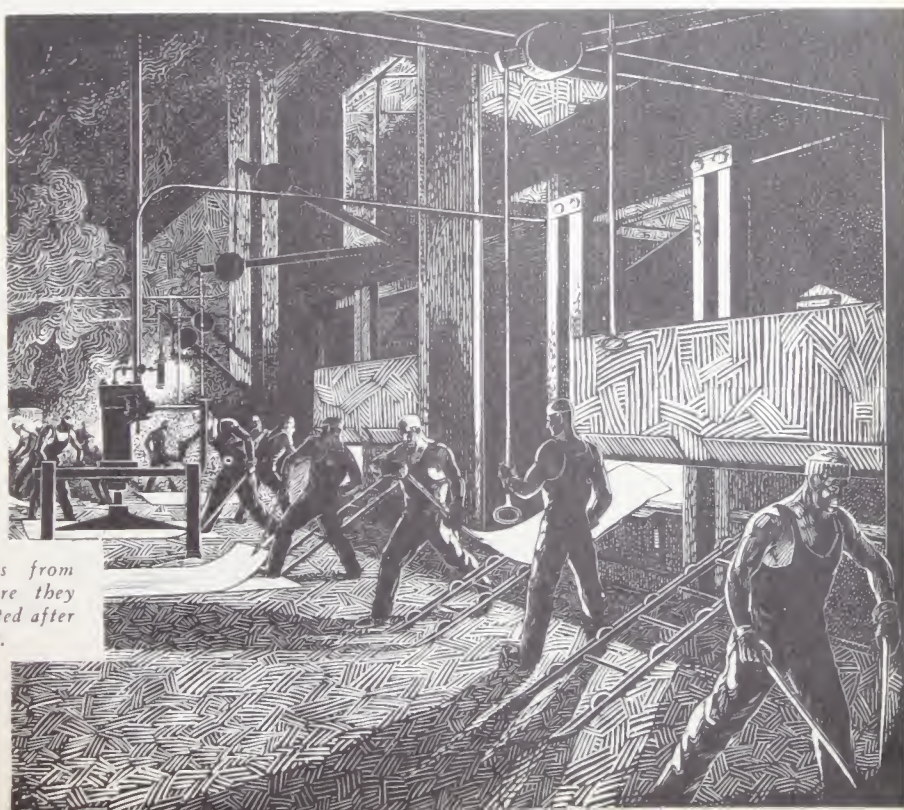
The sheet bars on arrival from the bar mill are cut by heavy shears into lengths which correspond to the desired width of the sheet to be rolled from the bar. Trained inspectors detect and discard bars which are laminated or otherwise unsound or which show surface defects.

The "rougner" of each mill crew feeds a bar through the rolls from one side. A "catcher" receives it on the opposite side. The "catcher" picks it up with a pair of tongs and passes it back over the top of the rolls. Meanwhile the "rougner" is passing a second bar between the rolls.

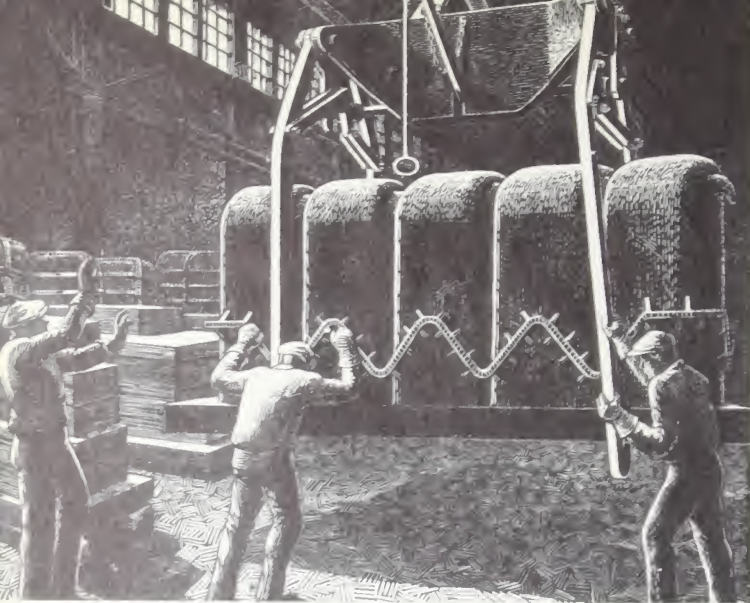
The entire operation is repeated again and again. Finally the bars have been reduced to a specified thickness. Both sheets, partly finished, are then rolled together until cold. Next, several sheets in the same condition are collected in a pack. They are bent double and placed in a sheet furnace to be reheated. When sufficiently hot, the entire pack is passed through the rolls to gain the desired thickness or gauge. After cooling, the sheets are sheared in packs and trimmed to size.

The sheet manufacturer considers this hot rolled sheet as a semi-finished product only. The various uses to which sheets are applied require the sheets to differ widely as to size, form, accuracy of dimensions, mechanical properties and surface conditions.

These hot rolled sheets are made flatter and the surface conditions are improved by passing the sheets through "cold rolls." The cold rolling mill resembles a hot mill in appearance. However, the cold mill requires more precision and care in its operation.



Taking sheets from furnaces where they have been heated after rolling.



Sheets are annealed in large air-tight boxes. This softens them and removes strains caused by rolling.

ANNEALING

CHAPTER XIII

SHEETS in the hot rolled condition are too hard and stiff for the majority of the uses for which they are intended. The hot rolled sheets are therefore annealed to soften them and to remove strains that have resulted from rapid cooling and rolling. Annealing means heating for 18 to 24 hours, or longer in many cases, at a temperature of 1400 to 1800 degrees Fahrenheit, and slowly cooling.

For this purpose the sheets are loaded in lots of 20 tons into heavy air-tight, cast iron boxes. Each box is run into an annealing furnace, or large square oven. Heat is applied and regulated by electrical recording pyrometers for the heating period specified. At the end of this heating period, a slow cooling process begins. The annealing boxes are taken from the furnace but the sheets remain in the boxes until their temperature has dropped to a point where they will not be affected by exposure to the air.

Sheets, after being annealed, are called "black sheets." They are ready for shipment for many commercial purposes. A proportion of the sheets, however, receive further protection to equip them to meet severe exposure to weather and other corrosive conditions. They are galvanized.

THE process of coating sheets with zinc, or spelter, is called galvanizing. Under similar conditions of service, galvanized sheets will outlast ungalvanized sheets.

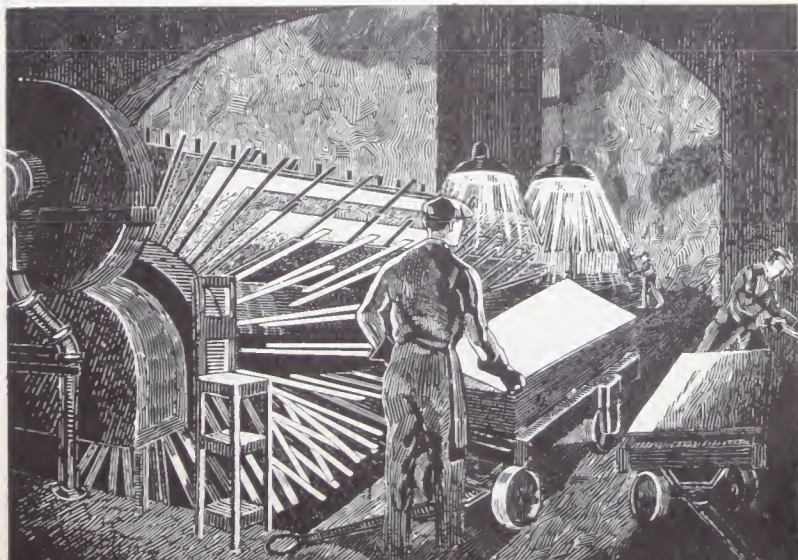
Galvanizing a sheet adds to its appearance, gives it additional protection from rust, and makes it suitable for soldering. As long as the zinc coating remains intact, the base metal cannot rust.

The first step in galvanizing is to clean, or "pickle," the sheets in a solution of hot sulphuric acid. This removes all the scale and dirt. A thorough washing in water follows. The sheets are then placed in tanks of muriatic acid in front of the galvanizing pot.

The galvanizing pot is a large square iron tank in which the zinc is melted. It is surrounded by a brick furnace, so arranged that heat is applied directly to the tank by the burning gas, oil or coke. A metal machine consisting of rolls, arms and gears immersed in the zinc, guides the sheets through the pot.

The top of the pot is open. The surface of the molten zinc is covered with a flux composed of melted ammonium chloride, or sal ammoniac. The flux gives the sheet a final cleansing and protects the molten zinc from oxidation.

From the muriatic acid the sheets are fed singly into the intake rolls of the galvanizing machine. Coated with zinc, they leave the pot and cool to the familiar spangle of galvanized sheets. They receive a final inspection. Then they are labeled and stored ready for shipment to meet the needs of industry.



*Inspection of sheets
after galvanizing.*



Left — Cross section of an ordinary galvanized sheet through the microscope. Note the sharp dividing line between the zinc coating above and the sheet below.



Right — Corresponding section of a galvanized sheet. Note the series of blending zinc-iron alloys resulting from the special heat treating.

GALVANNEALING

CHAPTER XV

WE HAVE said that as long as the zinc coating remains intact, the base metal cannot rust. In the usual applications of galvanized sheets, the zinc coating does not peel or flake from the base metal. On the contrary, it is uniformly adherent. However, the zinc coating has different physical properties than those of the iron or steel base metal. Absolute adherence of the coating under all conditions of fabrication, therefore, cannot be expected.

Whenever perfect adherence of the protective coating is essential, a sheet goes through a patented process called "galvannealing." The term "galvannealing" tells us, in view of what we have already learned, that a sheet is first galvanized and then annealed. It must be emphasized that the hot galvanized sheet is held and maintained at annealing temperatures before it is allowed to cool.

The art of galvanizing is based upon the fact that zinc will take iron into solution. We can say that the iron partly alloys with the zinc. The usual hot galvanized sheet chills quickly to room temperature. The iron cannot fully alloy with the zinc.

In the galvannealing process, we keep the freshly galvanized sheet hot for a few minutes and the iron fully alloys with the zinc. Thin layers of iron-zinc alloys are formed which blend into each other and into the sheet. The non-spangled galvannealed coating therefore becomes an actual part of the sheet.

The galvannealed coating insures that the base metal always has the additional protection no matter how severely the user may bend it or stamp it. Another and increasingly important feature is that paints will adhere much better to the true galvannealed sheet than to the galvanized sheet.

THE IMPURITIES IN IRON

CHAPTER XVI

FIVE basic impurities are present in all iron and steel used for commercial purposes. These impurities are carbon, manganese, sulphur, phosphorus and silicon. They are often referred to as "The Big Five Impurities."

In heavy sections of iron and steel, several of these impurities confer valuable properties at certain percentages. Sheets, however, do not require these properties. It is desirable therefore to rid sheet metal of as large a share of the impurities as can be done without injuring its quality. Subject to this consideration, reduction of impurities greatly increases the metal's resistance to rust and corrosion.

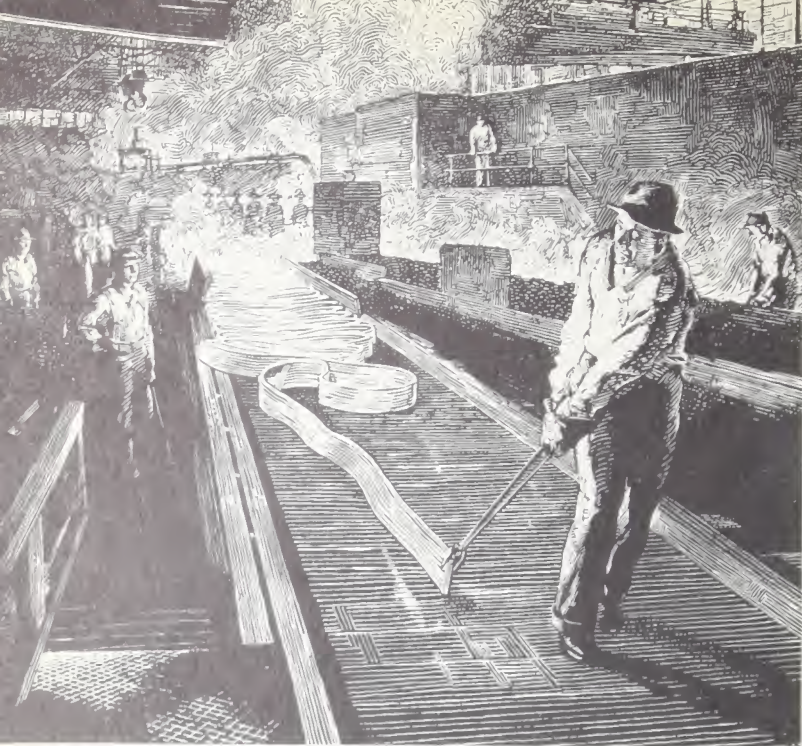
Carbon does not occur in iron ore. It is introduced as coke at the blast furnace, to aid in the ore's reduction, as described in the chapter on the Blast Furnace. It adds strength and hardness. But sheet metal must be comparatively soft and ductile to permit forming operations. So the carbon content must be reduced to a percentage low enough to yield these properties and yet not to affect the metal's corrosion-resistance.

A small percentage of manganese is carried through the refining process from the ore. More manganese is added during refinement as an aid to rolling. The iron can be rolled more rapidly. The manganese also helps offset the brittleness caused by sulphur when the metal is being worked hot.

If too large an amount of manganese is present in the sheet, it will accelerate corrosion. On the other hand, reduction of the manganese content to the lowest possible percentage is equally harmful. The extra oxygen required for such reduction oxidizes or "burns" a considerable amount of the iron itself. Careful practice and scientific inves-



The black triangle at the bottom represents the total amount of impurities in Toncan Iron—less than $\frac{1}{4}$ of 1%.



*Hot strip headed for
the coiler in one of
Republic's large strip
mills.*

tigation have determined the exact amount of manganese necessary to improve rather than to injure the quality of the iron.

Sulphur is the most difficult of all the impurities to remove from iron. It occurs in the ore. It offers no beneficial properties. In fact it accelerates corrosion. Beyond a certain slight percentage, it also tends to make iron brittle when hot. Selection of ore of low sulphur content, followed by vigilant refining methods, is required to reduce the percentage of sulphur to a point where it will have no harmful effects.

Phosphorus is another impurity carried over into iron from the ore. It serves no useful purpose. Aside from its tendency to segregate, an appreciable amount will make iron and steel brittle when cold. It can be reduced to a harmless percentage.

Silicon also originates in the ore. All silicon with the exception of small traces is removed in the refining process. However, because silicon gives desirable electrical properties to steel, it is not removed when steel is especially made for such applications.

PURITY AND UNIFORMITY

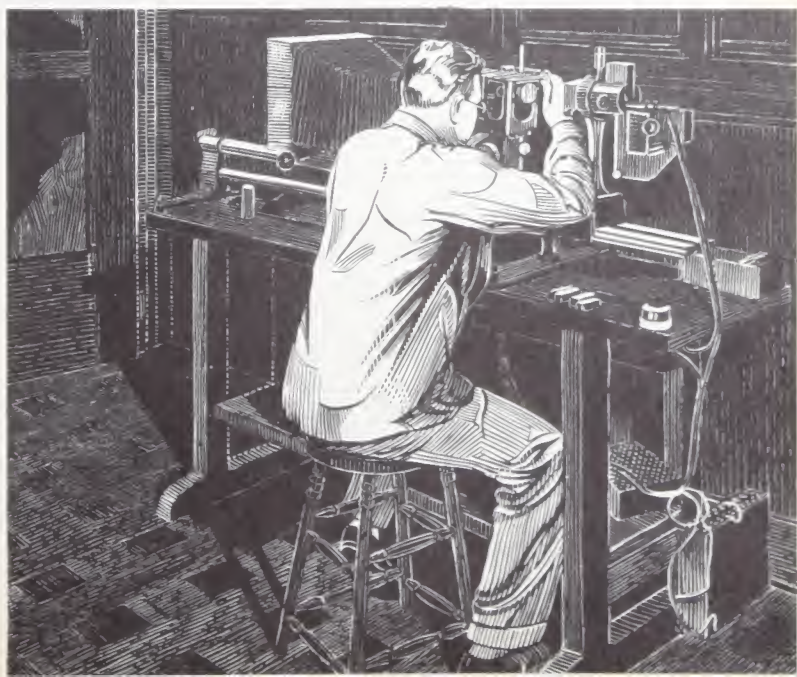
CHAPTER XVII

STRICTLY speaking, no iron available for commercial use can be classed as chemically pure metal. Pure iron, free from every trace of impurity, is far more rare than any of the so-called precious metals, such as gold and platinum.

Pure iron, as we have already noted, does not occur in Nature, save as a visitor from other worlds in the form of meteorites. Few of us have ever seen the silvery whiteness of pure iron.

Even in a laboratory, iron of 100 percent purity is extremely difficult to produce. In well-made sheet iron we find that the percentage of impurities has been reduced to the lowest proportion which its maker considers consistent with the iron's maximum value as a commercial product. Its total percentage of impurities amounts to but a small fraction of a single percent. Such iron is commonly called "pure." But it is generally understood that it is only "commercially pure." At the same time there may be a marked difference in the aggregate percentages of impurities of "pure" irons.

We have pointed out in a previous chapter how the presence of an excess of one or more impurities in iron may hasten the attack of cor-



*A scene in Republic's
metallurgical labora-
tories where research
work is continually
carried on.*



Enormous quantities of sheets in various sizes and gauges must be kept in stock for market demands.

rosion. It might be inferred from this that the purer the iron the more resistant it is to corrosion. This is true only within certain limits.

The reduction of impurities in iron may be likened to the erasure of an ink blot from a sheet of paper. Most of the ink may be removed readily. But the last few traces are much harder to remove. In fact, it is impossible to do so without injury to the paper.

And so in iron-making we find that the smaller the percentages of impurities in the iron, the greater the difficulty of their further reduction without harm to the final quality of the iron. Complete elimination of the impurities would make the iron unfit for service. The cost of such elimination, moreover, would be prohibitive.

Even more important than purity to the character of sheet iron is its uniformity. By uniformity we mean that the chemical analysis and grain structure are the same everywhere in the sheet. Hence, the slight amount of impurities remaining, after refinement, in a corrosion-resistant sheet will be well distributed.

Uniformity is vital. It is obtained through utmost care in production methods. Without it, a high standard of commercial purity is of little value. Purity alone may slow up rusting, once it has begun. With uniformity, the sheet will retard that first attack.

RUST AND CORROSION

CHAPTER XVIII

THE length of life, or durability, of iron and steel depends largely upon their ability to resist rust and corrosion.

Rust and corrosion revert ferrous materials to their former state, i. e., iron oxide. Authorities have recently estimated that the world's total annual loss of iron and steel through corrosion approximates one and one-half billion dollars, equivalent to almost one-half of the normal annual production of steel in the United States.



Rust destroys more wealth than do fire, flood and storm combined.

Remember that it takes from three to four pounds of coal alone to produce one pound of iron. The labor and other items of cost are also considerable. Small wonder that rust and corrosion are regarded as giant wasters of the world's wealth. Directly or indirectly, every person and every branch of business are taxed by their ravages.

Although the use of the two terms, "rust and corrosion," might suggest that they are two separate and distinct agencies, rust is really a form of corrosion. The name rust refers to a condition applicable only to metals made from iron ore. Rust may be classified as "general selective corrosion," which occurs uniformly over the whole surface of a metal. For the purposes of our present discussion, we shall use the term "corrosion" to refer only to the second main type of attack, called "localized selective corrosion." It occurs in spots and is also called "pitting" or "tubercular corrosion."

Let us first consider rust, which is the most common evidence of corrosive action. Rust is really an iron oxide formed when an iron surface is dissolved and oxidized by moisture and oxygen. When a drop of water falls on a clean bright surface of iron, the drop stays clear for a short time. We can see the bright surface of the iron



A photograph of a sample of corrugated galvanized Toncan Iron.

through it. But soon it takes on a greenish appearance, showing the solution of the iron by the water. Presently this compound absorbs oxygen and turns reddish brown. This is rust.

The rust does not stick to the iron at first, but is suspended in the water. It becomes a coating when the water has evaporated. Iron remains quite free from rust in an atmosphere containing water-vapor, so long as the water-vapor does not condense as liquid water on the surface of the iron. But when rust once forms, the iron will go on rusting in an atmosphere in which a piece of clean iron will not rust. This is because water will condense on rust when it will not on bright iron. Thus it is much easier to prevent the first formation of rust than to stop the process.

Rust launches its attack uniformly upon the surface of metal, when the latter is exposed to moist air or to water containing acids or certain other corroding agents. With its large surface area, sheet metal stands in particular need of protection from such exposure, even though it may be inherently rust-resistant.

Any method which will retard the attack of rust, of course, serves to increase the life of the metal. Hence, protective coatings are widely employed to ward off such attack. Paints, enamels, japans and various metals, such as lead and zinc, are familiar examples.

For comparative purposes we might liken rust to a skin disease spreading its blight over the outer surface of the human body. Corrosion, on the other hand, is like tuberculosis, except that once started its ravages cannot be checked. Rust and corrosion are accelerated by

conditions from within the body of the metal. Their progress may be hastened by favorable atmospheric conditions.

Faulty conditions in the metal promote rust and corrosion. Strains, uneven and spongy grain structure, excessive amounts of harmful impurities, and the failure of these impurities to be distributed uniformly throughout the metal are leading causes of corrosion.

The segregation of impurities is probably the most powerful of these causes. Impurities have a tendency to group together in the sheet during its solidification in the ingot. The segregation induces an electro-chemical action. The differences in chemical composition which exist in very small areas cause one part of the sheet to become anodic (positive) and another cathodic (negative). Hence a battery action continues in which that part of the sheet which becomes the positive pole has what we term a higher "solution pressure," or tendency to go into solution, than the negative pole.

Wherever electro-chemical action begins, reddish-brown spots appear. Aided by the action of air and moisture, the spots grow larger. The metal begins to flake off. Tiny holes appear in the surface of the sheet. These holes rapidly grow larger. Finally, the entire sheet has crumbled away.

The rust and corrosion problem directly affects all industry. It adds to the production cost of practically all our commodities of life. It causes shut-downs of machinery and plants for repairs. It causes unemployment. It occasionally results in contamination of manufactured products, notably in the chemical industry.

It is not to be wondered at that modern industry has come to realize the urgency of controlling or reducing the heavy toll of loss due to rust and corrosion. More than ever before, science is focusing its spotlight of research upon methods of combating their attacks. We shall see how this research already has met with considerable success.



A multi-motored Boeing transport plane, the fastest of its kind in the world. All steels are used to give it great strength and light weight. The exhaust manifold collector rings made of Enduro, the public's Perfect Stainless Steel.

THE AGE OF ALLOYS

CHAPTER XIX

AN ALLOY may be defined simply as a material having metallic properties and consisting of two or more elements, of which at least one is a metal. Thus an alloyed ferrous material is an alloy of one or more elements with iron or steel for the purpose of improving one or more properties of the iron or steel.

So varied are the applications and so beneficial are the results that alloyed iron and steel production in 1929, a peak year, amounted to 7% of the year's total tonnage. Industry and science are so firmly convinced of the great importance of alloy ferrous materials in the future that a tremendous amount of research and development work is being carried on in this field. Through proper chemical composition, heat treatment and processing, steels are being "built" to satisfy increasingly severe requirements. So marked is the trend to this practice that there is now a tendency to call this "The Age of Alloys" rather than "The Age of Steel."

It has long been known that the admixture or alloy of two or more metals may serve useful purposes which neither metal alone could serve. Brass as an alloy of copper and zinc, and bronze as an alloy of copper,

zinc and tin, were highly valued by people living even in prehistoric times.

Gold and silver, unalloyed, are soft and easily worn away. They are usually hardened by alloying them with other metals in varying proportions. Sterling silver, for example, is composed of 92.5 parts silver and 7.5 parts copper. Even the coins of trade, ancient and modern, testify to the value of the art of alloying.

Alloys of copper, chromium, nickel, vanadium, tungsten and molybdenum—the more useful elements—with iron and steel are already fulfilling important requirements in the industrial world. Elements, of which a short time ago little was known, are becoming necessary tools for the alloy steel manufacturer.

The manifold specifications which alloys are meeting are rust-resistance, heat-resistance and stainlessness. High strength and impact resistance of alloys are utilized in automobiles, airplanes and locomotives to make them more efficient and lighter in weight. Extreme hardness and wear-resistance result from the proper combination of alloy elements. Specific thermal and electrical properties are characteristic of some special alloyed steels.

When alloyed irons and steels are mentioned, the average reader thinks in terms of improved physical properties. However, the ability of alloy additions to confer stainlessness or rust-resistance is equally important and valuable.

Enduro Stainless Steels

Probably the most unique of all alloys are those commonly called "stainless steels." Alloys of this type produced by Republic Steel Corporation, world's largest makers of alloy steels, are known as ENDURO Stainless and Heat-Resisting Steels.

A large number of types of ENDURO have been developed to meet specific service conditions. The all-purpose type is called ENDURO 18-8 Stainless Steel. It is composed of approximately 18% chromium, 8% nickel and the balance iron. This alloy does not rust or tarnish. It is stain-free. It is stronger than ordinary steel. It is a white metal

which closely resembles platinum or silver when polished. It is not harmed by foods and food juices. Most acids and chemical reagents fail to affect it. It is cleansed merely by washing with soap and water and retains its beautiful lustre almost indefinitely.

Various types of ENDURO Stainless Steel are used extensively for cooking utensils and equipment, soda fountains, sinks and drainboards, hospital, restaurant and hotel equipment, dairy machinery, canning and meat packing equipment, brewing and distilling apparatus, textile machinery, pulp and paper-making equipment, architectural applications, marine hardware, aircraft and automobile parts and many other widely varying applications. So versatile is this alloy that it has been aptly called, "The Metal of Ten Thousand Uses."

Stainless steel with high carbon was originally developed for cutlery use and has proved highly successful for that application. However, this type is not adapted for forming, deep drawing and other fabricating operations. The stainless alloys which can be formed successfully are low carbon alloys of iron and chromium, or of iron, chromium and nickel, such as the ENDURO group. Republic Steel Corporation, with its electric furnace-made ENDURO Stainless Steels, is playing a leading part in the development, manufacture and application of these unique materials.

The Benefits of Copper

A triumph of modern metallurgy came with the discovery of the value of copper as an alloying element to well-made iron and steel. It was found that copper, when alloyed in proper proportion, adds greatly to the rust and corrosion-resistance of these metals.

Research by commercial and independent scientists about the beginning of the present century had already revealed the presence of small percentages of copper in many of the samples of early irons which had resisted corrosive action over long periods of time. Their investigations led them to believe that the durability of much of the iron of centuries ago was due in some degree to the presence of copper.

The iron workers of ancient times, however, were not able to reduce the iron to a liquid state. Hence they could not have added copper to their iron even had they so desired. The copper, in varying percentages, was carried over from the ore.

Many grades of iron ore today contain copper. Carried over into the finished iron in such slight percentages as .05%, it exerts some beneficial effect on the iron's corrosion-resisting properties. Maximum benefits from copper in iron or steel are not derived, however, except when copper is alloyed with the molten iron in considerable proportions, usually from .20% to .50%, sometimes even higher.

Copper is now widely used as an alloying element in sheet iron and steel. The copper enters into solid solution with the base iron or steel and forms a true alloy. The resultant alloy has gone far toward cutting down the enormous losses caused by rust and corrosion.

Spurred by the success attained through the use of copper, metallurgical science is constantly searching for new alloys which will make still further advances in retarding rust and corrosion.

The Burlington "Zephyr" — all stainless steel streamlined train. The alloy steel used in this train is so strong that smaller sections are used. The whole train weighs about as much as one ordinary Pullman car.





Toncan Iron roofing and siding, properly grounded, make farm buildings safe from lightning's threat.

THE STORY OF TONCAN COPPER MOLYBDENUM IRON

CAREFUL study of rust and corrosion-resisting irons which had survived from earlier centuries led investigators at the beginning of the present century to an important discovery. This was that such irons were remarkably free from the natural impurities and that an excess of such impurities tends to hasten rust and corrosion. These long-lasting irons possessed both purity, as we now use the word in a commercial sense, and uniformity. These two qualities probably resulted from the efficiency of the old hand-working methods of making iron. It was an efficiency of quality if not of quantity.

The development of commercially pure sheet irons followed this scientific discovery. Industry soon obtained sheet metal of higher and more uniform resistance to rust and corrosion than that of ordinary iron or steel sheets.

The Beginnings of Toncan Iron

In this development Republic Steel Corporation, now the world's largest and most highly specialized producers of alloy steels, was a pioneer. In 1908 it began the commercial production of a commer-

cially pure iron which it called Toncan Iron. The name Toncan was formed by reversing the syllables of the city where it was manufactured—Canton, Ohio.

The early claims of durability for the pure irons were well founded. Countless installations of Toncan Iron during the first years of its production are yet in service. Iron and steel sheets of the ordinary kind averaged hardly three or four years of service under similar conditions of exposure. It can thus be seen how valuable to industry was the development of Toncan Iron and other well-made irons.

Meanwhile science continued its research. Purity and uniformity were developed to the limits of their possibilities as aids to corrosion-resistance. The careful selection of raw materials and the skill and scientific control used in the manufacture of Toncan Iron offered scant opportunity for further development. The manufacturers of Toncan Iron were not satisfied with a product so restricted in the possibility for improvement in rust-resistance. They felt that this resistance could be developed through other channels, and research work was begun to develop means of producing additional rust-resistance.

Sugar Grove Camp, Dayton, Ohio, where salesmen of the National Cash Register Co. gather each year to lay sales plans. Toncan Iron sheets are used for air-conditioning equipment.





Kennett Square Consolidated School, Kennett Square, Pa. — largest school of its kind in the world. Toncan Iron is used for all interior sheet metal work.

Copper Added to Toncan Iron

Being pioneers in the manufacture of alloyed irons and steels, it was only natural that alloy additions were investigated for this purpose. We have already noted in an earlier article that scientific investigators had traced the presence of copper in many of the old-time irons possessing exceptionally long life. Accidental though its presence was, it had much to do with their resistance to the elements, science believed. Exhaustive tests bore out this conclusion.

The addition of copper in the making of both iron and steel now became an established method of sheet metal production. The results were far reaching. Proof was had as to the value of the alloying principle—in this case, copper with a well-made refined iron—as a means of obtaining the maximum resistance to rust and corrosion. The beneficial effect of copper is most utilized when it is alloyed with a well-made open hearth iron refined to reasonable limits.

And since copper has been proven so effective in this direction, why might not some other alloying element be developed as an additional source of rust and corrosion-resistance? So reasoned science in its tireless search for truth.

Hardly had the makers of Toncan Iron begun to fortify their product with copper before their laboratories started research aimed toward still further improvement. They were committed to a permanent policy of giving to Toncan Iron the benefit of every new mechanical or metallurgical process which would make it a better product.

The Discovery of Molybdenum's Value

It came about that Republic Steel metallurgists in their search for improvement of Toncan made one of the supreme discoveries in the history of modern metallurgy. They discovered the value of molybdenum as an alloying element in checking still further the losses caused by the destruction of iron by natural forces.

Even before the World War the value of molybdenum for certain alloying purposes was well known. But it was during the war that Republic Steel Corporation became the first to develop methods for the successful use of molybdenum in the production of iron and steel.

Molybdenum gives steel increased tensile strength. It imparts great additional power to withstand shock and impact stresses. Molybdenum steel is employed extensively today for gun linings, airplane struts, propeller shafts, and for automobile and locomotive parts.

Like copper, molybdenum occurs as a native ore in the United States. It is refined either to a greyish-colored metal or to a black powder that resembles graphite. The chief sources of commercial supply at present are the huge deposits in Colorado and New Mexico.



In 1913 The Chicago Rapid Transit Co. roofed 250 elevated passenger coaches with Toncan Iron. To date not a single sheet has been replaced because of rust or corrosion.

The Goodyear-Zeppelin Airdock at Holmes Airport, Long Island, N. Y., is used to house Goodyear blimps. All exterior and other sheet metal is Toncan Iron.



Toncan Iron metallurgists determined, after repeated tests, the correct amount of molybdenum to combine with copper and refined iron. The resulting copper molybdenum iron alloy possesses a rust-resistance not equalled by ordinary iron or steel sheets.

The Influence of Molybdenum

Of particular interest and value in molybdenum is the influence it exerts on other elements of the same alloy. In iron and steel alloys containing nickel, chromium, vanadium, copper or certain other alloying elements, the presence of molybdenum actually increases and intensifies the beneficial properties of these associated elements.

In their research to add new years to the life of Toncan Iron, Republic Steel metallurgists brought to light fresh proof of molybdenum's influence. They proved that in Toncan Iron it works both as a positive and as a negative force.

In a positive way, it increases and intensifies the benefits of the copper addition. In a negative way, it combats certain injurious tendencies of the natural impurities remaining in the iron.

But molybdenum's chief contribution to Toncan Iron is that it produces and maintains a refinement of grain structure. The grain structure of Toncan Iron is not distorted when the sheet is cold worked. Therefore Toncan Iron possesses a distinctive property in that cold worked areas have practically the same rust-resistance as unworked areas. More technically expressed, stressed sections of Toncan Iron have practically the same rust-resistance as unstressed sections. Accelerated laboratory tests, long-time weather exposure tests and service records all prove that this is true.

Accelerated Corrosion Tests

Accelerated corrosion tests are employed by scientists in order to determine the comparative rust-resistance of ferrous materials within as short a time as is consistent with good testing practice. In these tests the ferrous materials are subjected to corrosive attack under conditions which are comparable with the conditions during actual service.

Warehouse of the American Tobacco Co., Durham, N. C., where Lucky Strike cigarettes are stored. Ten tons of Toncan Iron used for sheet metal work.





Rockefeller Center, or Radio City as it is commonly known, is one of the largest building projects in the world. Several hundred tons of Toncan Iron Pipe were used in the air-conditioning system of the NBC Studios. Toncan Enameling Iron was also used in the marquis on the Radio City Music Hall.

For instance, ungalvanized samples of the various metals are submerged in 20% sulphuric acid solution or they may be subjected to a spray of weak acid. In fact many such tests may be easily and rapidly conducted. The sulphuric acid test is logically based on the fact that ferrous materials fail in the atmosphere because of the combined forces of sulphur, water and air. An acid or other corrosive substance likewise selectively attacks the points of weakness, often hidden, of the sheet. In this way we can show the comparative soundness and uniformity.

Within a period of time that may range from one to six months, the samples undergo a loss in weight, the severity of which will approximate that of most conditions of outdoor service over a period of several years. The percentage of loss in weight suffered by each sample is the index of its corrosion-resistance.

The Verdict of Accelerated Tests

The results of thousands of such accelerated tests leave no room for doubt as to Toncan's superior durability. They show Toncan to possess

corrosion-resistance far greater than that of unalloyed iron and of copper-bearing steel. The story told by these tests has been verified repeatedly by similar tests conducted by industrial laboratories and independent scientists.

It should be understood, of course, that these laboratory tests do not make it possible to determine the number of years which a given metal will serve. Tests are of value only to foretell the relative order of failure when the several metals are exposed to atmospheric conditions. In other words, the order of failure in the short-time tests generally will be the order of failure in service.

In a weather exposure test typical of many others conducted by Toncan metallurgists ungalvanized samples were exposed side by side



"City of New York" in which Rear Admiral Byrd made his famous trip to the South Pole. The ship is shown here as it was exhibited at A Century of Progress Exposition, Chicago. Toncan Iron boiler tubes are an important part of its equipment.



Sterling Law School, Yale University, New Haven, Conn. One of several Yale buildings where Toncan Iron is used for ventilating and sheet metal work.



Arlington Memorial Bridge, Washington, D. C. This monumental structure bridges the famous Potomac River at the nation's capital. The bascule span is faced with ornamental panels of Toncan Iron.

to the weather for one year. The site of the test was between a steel mill and railroad yards. This location made the test unusually severe because of the large volumes of sulphurous smoke present in the air most of the time.

The sample of plain steel had been almost entirely eaten away by corrosion, at the end of the test period. The sample of unalloyed iron showed numerous large and small holes through the sheet. The Toncan sample revealed not so much as pin-hole evidence of corrosion.

Evidence such as given by accelerated and weather exposure tests properly conducted along lines approved by scientific authorities cannot be questioned. They afford conclusive proof of Toncan Iron's exceptional durability. In this connection, it may interest our readers to know that the metallurgical laboratories in which Toncan Iron's manufacture is controlled are the largest and best equipped in America.

How to Conduct a Simple Test

For those of our readers who may desire to conduct a simple accelerated test in order to determine for themselves the comparative corrosion-resistance of Toncan Iron and other metals, the following is suggested:

Place samples of the uncoated metals to be tested in separate glass jars. Cover them with a solution of 20% sulphuric acid. Allow the samples to remain completely immersed for one week, at ordinary room temperature. Remove and wash in water. Dry the samples and examine the appearance of each. The test can be made more exact by weighing each sample before and after immersion. The above opera-

tions should be repeated until one or more of the samples has failed, i. e., when there is a hole in it. Care in handling the acid should be taken, for solutions of the strength suggested are strong enough to burn the flesh and to destroy clothing.

Typical Chemical Analysis and Physical Properties of Toncan Iron Sheets

Toncan Copper Molybdenum Iron is an alloy of open hearth iron, refined to reasonable limits, with which is alloyed a correct proportion of copper and molybdenum.

A typical analysis of Toncan Iron sheets, showing the content of impurities and alloying elements, is as follows:

Carbon .....	.03%
Manganese .....	.12%
Sulphur .....	.032%
Phosphorus .....	.008%
Silicon .....	.005%
Copper .....	.45%
Molybdenum .....	.07%

Physical properties of Toncan Iron in sheets are approximately as follows:

Tensile Strength, 50,000 lbs. per sq. in.

Yield Point, 34,000 lbs. per sq. in.

Elongation in 2", 36%.

Reduction of Area, 65%.

Rockwell Hardness (Scale B), 40.

Many thousands of feet of Toncan Iron Culverts have been used in flood prevention work in the Mississippi Valley. This view shows work being carried on in Missouri.





The new Seattle Museum, Seattle, Wash., is an architectural masterpiece. Toncan Iron is used for all interior structural metal work.

Toncan Iron is Easy to Form

The forming qualities of Toncan sheets are unsurpassed. The metal is softer and more ductile than mild steel. In thousands of sheet metal shops throughout America, Toncan Iron is favored almost as much for its easy workability as for its durability.

Other qualities possessed by Toncan Iron also deserve mention. It can be welded by any method. It can be machined and forged. Toncan Iron is suitable for almost every purpose for which iron and steel can be used, save where great strength and hardness are required. It is available in sheets, bars, billets, plates, tubes, pipe, wire and most other forms in which iron and steel are produced.

Varied Uses of Toncan Iron Sheets

Toncan Iron is in wide use for architectural sheet metal work, such as roofing, siding, cornices, canopies, ventilating ducts, eaves trough, gutters, downspouts, flashing, hoods, blower pipe, metal lath, skylight and window frames, and furnace pipe.

Several large manufacturers of metal garages, filling stations and structures of similar type depend upon Toncan Iron exclusively for their products.

The drainage of water from numerous railways, principal highways, swamps, airports and golf courses is accomplished through the use of

Toncan Iron corrugated pipe and perforated corrugated drains. The durability, flexibility and load-bearing strength of Toncan Iron corrugated culverts and drains make them a more economical installation than non-metallic or other metallic structures.

For years engineers have sought an economical drainage structure in the form of a large culvert or a small bridge that would embody many essential features. These features are the ability to resist both rust and the loads borne by rigid structures. Also live loads and impact from traffic when the culvert is under shallow covering must be absorbed by the culvert. The stress introduced because of uneven, pervious and soft foundations must be equalized by the drainage structure. Of importance, frost and ice are always enemies of culverts.



Toncan Iron Enameling stock is used for this giant sign at the retail store of Sears, Roebuck & Co., Boston, Mass. The sign is 48 ft. high.

The home of Miss Katherine Kelly, Scarsdale, Long Island, N. Y., is an excellent example of modern residence design. Toncan Iron is used for gutters, soffits, exterior walls above the brick work and for copings around the decks.





Bernard Albert Hall, University of Chicago, Chicago, Ill. Toncan Iron is used in both hot and cold water lines.

With these exacting specifications in mind, Toncan Iron Sectional Plate Pipe was developed. It is rapidly taking the place of other structures.

Makers of refrigerators, washing machines, stoves, warm air furnaces, ventilators, electric signs and a large number of other manufactured products common to our daily life use Toncan Copper Molybdenum Iron in either the black, galvanized, galvanized or cold rolled finishes.

Toncan Iron Enameling stock is a highly refined open hearth iron. A Toncan Iron Enameling sheet is custom-processed to satisfy the varied porcelain requirements of the enameler and the difficult forming operations of the fabricator. Refrigerators and stoves which carry the trade-marks of many of the leading manufacturers have Toncan Iron Enameling sheets in the porcelain enameled parts. Many porcelain enamel signs which advertise nationally known commodities are made from Toncan Iron Enameling stock.

On farms, Toncan Copper Molybdenum Iron is in large demand. As roofing and siding on houses, barns and sheds, it gives protection against three of the farmer's chief enemies: rust, fire and lightning. Toncan Iron is also ideal for grain bins, water troughs, ventilators, culverts, flumes and other agricultural installations.

Toncan Copper Molybdenum Iron Pipe

* The building industry places severe demands on piping systems. Water and gas services from street mains to homes, hospitals and other buildings must not fail. Hot and cold water lines for plumbing systems and steam mains and condensate returns of heating systems are subjected to continued service. Rust and corrosion play havoc with many piping materials in these services. Selection of the proper material for these various services, therefore, is an exacting duty of architects and engineers in the building and industrial fields.

Failure of oil well, refinery and transportation tubing and pipe lines, as well as failure of salt well and refinery tubing and pipe lines have cost those industries huge sums. Boiler tube failures in locomotives and steamships mean delays and frequent repairs.

Since the introduction of welded iron pipe one hundred or more years ago, individuals, groups, associations and corporations each have had to contend with just such inconvenience and expense. For that length of time manufacturers of ferrous pipe have made an effort to increase the resistance of their pipe to rust and corrosion.

Pipe made of Toncan Copper Molybdenum Iron has been more successful than its forerunners in combating rust and corrosion. It pos-

Modern kitchens are cheery workrooms, well supplied with labor-saving equipment. Leading manufacturers of ranges, refrigerators, kitchen tables, cabinets, sinks, etc., use Toncan Iron Enameling sheets.





The plant of International Harvester Co. Dodge City, Kas. Over 35 tons of Toncan Iron were used for roofing and siding on this building.

sesses greater resistance to rust and corrosion than any commercial ferrous material in its price class. Threaded areas, or sections otherwise cold worked have practically the same rust-resistance as the unworked areas. Its physical properties—sufficient strength, high ductility and impact-resistance—are desirable. The ease of weldability of Toncan Iron Pipe is common knowledge among its users.

It has been of special value to the consuming world, therefore, that



Toncan Oven Lining is shipped all the way to Holland to make this Dordrecht Gas-cooker, manufactured by Maatschappij ter Vervuurdiging Van Gasometers, enz., Dordrecht, Holland.

One of the many U. S. Government light-houses which safeguard marine transportation. Toncan Iron gutters and spouting are used here.



Toncan Copper Molybdenum Iron is available in the form of pipe and other tubular products.

The Pledge to Progress

In this story of Toncan Iron we have wished to state only facts. We have understated, rather than overstated, the claims for Toncan Iron. We invite our readers to determine for themselves, insofar as

The Jacksonville, Fla., plant of the Ford Motor Co. Toncan Iron lath is used here because of its resistance to salt air corrosion.





The Broad Street Station of the Pennsylvania Railroad, Philadelphia, Pa. Nearly five tons of Tensar Iron are used for ventilating ducts in the building and a large quantity in an extension made recently.



Tensar Iron is used for the dome of the Dominion Astrophysical Observatory, Victoria, B. C., Canada, built in 1911. According to the Director, "from present indications there seems to be no reason why the metal should not stand up for a century or more."

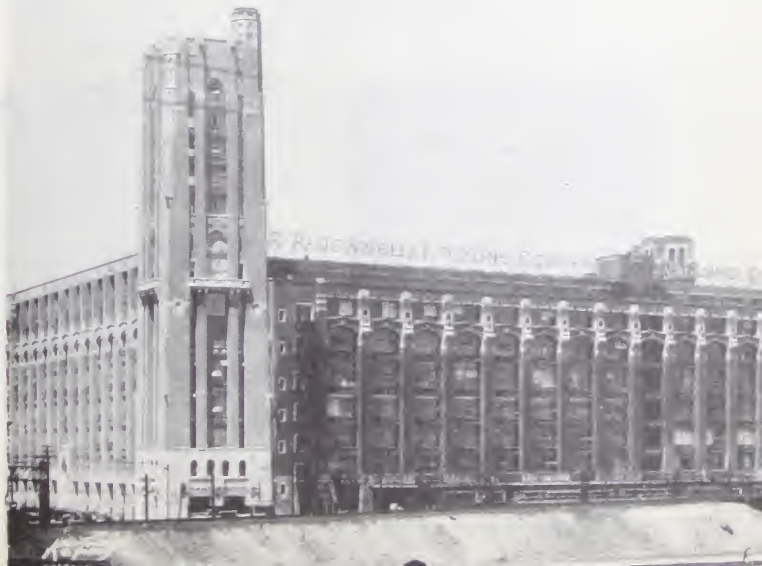


The Country Home Model Farmhouse at A Century of Progress Exposition, Chicago, Ill. Toncan Iron eaves trough and downspouts are used in this ideal farm residence.

they may be interested, the truth of all claims which we have made for Toncan Iron.

In conclusion, the Toncan Iron of today represents an achievement founded upon more than 25 years of metallurgical study, technical skill and large tonnage production. First came the production of commercially pure iron. Yesterday came the copper-iron alloy. Today Toncan Iron is a copper-molybdenum-iron alloy. Tomorrow, in keeping with our pledge to progress, Toncan Iron will be still further improved by scientific discovery, if possible.

The Lakeside Press of R. R. Donnelley & Sons Co., Chicago, Ill., largest printing plant in the world. About 300 tons of Toncan Iron were used for heating and ventilating ducts.





Photograph of a 26-gauge ungalvanized sample of unoxidized iron exposed to the weather under exactly the same conditions as Tuncan Iron. Rust and corrosion have eaten large holes in this sample.



Photograph of a 26-gauge ungalvanized sample of Tuncan Copper Molybdenum Iron which had been exposed to the weather for one year. Compare this with the sample at the left.



TUNCAN

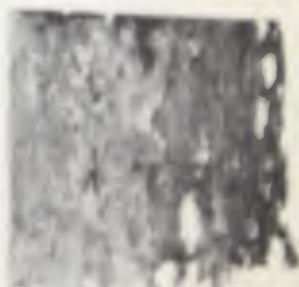


STEEL

Tuncan Copper Molybdenum Iron tube is here compared with tubes of steel, charcoal iron and wrought iron in the standard 20% sulphuric acid test. At the end of a week in the acid the Tuncan Iron tube had lost 10.4% of its original weight, whereas the steel tube lost 24.5%, the charcoal iron 74.4% and the wrought iron 44.2% of the original weight.



CHARCOAL IRON



WROUGHT IRON

TONCAN IRON QUESTIONNAIRE

1. *What is Toncan Iron?*

Toncan Iron is a short name for Toncan Copper Molybdenum Iron—a highly refined open hearth iron with which is alloyed copper and molybdenum in correct proportions to give maximum resistance to rust.

2. *By whom is Toncan Iron manufactured?*

Republic Steel Corporation, with general offices at Youngstown, Ohio.

3. *For what uses is Toncan Iron recommended?*

Toncan Iron is recommended particularly for its resistance to rust in all cases where a ferrous metal is indicated. In addition to high resistance to rust, Toncan Iron is unusually soft and ductile. It can be formed into any commodity which is ordinarily made of iron or steel.

4. *Can Toncan Iron be worked or fabricated?*

Toncan Iron can be easily worked either hot or cold. It can be welded by gas or electric process, soldered, brazed, riveted, spun, etc. It may be coated with various protective coatings. It can be galvanized, sherardized, tin and terne-coated.

5. *What is a typical chemical analysis of impurities and alloying elements in Toncan Iron?*

Carbon .....	.03%
Manganese .....	.12%
Sulphur .....	.032%
Phosphorus .....	.008%
Silicon .....	.005%
Copper .....	.45%
Molybdenum .....	.07%

Toncan Iron is not sold on analysis but for its high degree of rust-resistance. We reserve the right to change the analysis without notice at any time, should we find that by so doing we increase its rust-resistance.

6. *What proof do we have that Toncan Iron is an iron and not a steel?*

Aside from the chemical analysis, irons are identified first, by their ferrite structure which is the characteristic micro-structure of chemically pure iron; second, by the thermal range—that is, all irons are brittle when hot between certain ranges of temperature. Neither of the above characteristics is found in steel. Third, all irons have lower ultimate strength but higher elastic limit and greater elongation than steel. Toncan conforms to all of the above requirements for iron.

7. *What are the purposes of copper and molybdenum in Ticon iron?*

Copper increases resistance to rust and corrosion, when added to a well-made iron. Molybdenum increases the effect of copper and prevents the use of an increased amount of copper. Both the copper and the molybdenum are completely dissolved in the iron. The resultant metal is a uniform, fine-grained alloy, possessing a greater resistance to rust and corrosion than that of any other ferrous metal known today, excepting only the stainless steels and alloys.

8. *What are the physical constants of Ticon iron?*

Specific Gravity—7.88 approximately. Slightly greater than that of ferrous products, about 1%, which is reflected in its uniformity of resistance to attack.

Electrical Conductivity—About 11 1/2% that of copper.

Thermal Conductivity—Slightly better than steel or iron products.

Coefficient of Expansion—0.00000674.

Melting Point—2775° F.

9. *What are the physical properties of Ticon iron?*

Tensile Strength, lbs. per sq. in.	45,000-55,000
Yield Point, lbs. per sq. in.	10,000-40,000
Elongation in 2", per cent	10-40
Reduction of area, per cent	40-70
Rockwell Hardness (Scale E)	58-68
Brinell Hardness	80-110

10. *In what forms can Ticon iron be furnished?*

Ticon iron can be furnished in practically every form in which iron or steel is produced, namely, plates, sheets, bars and cold rolled strip, hot rolled and cold drawn bars, wire, shapes, welded and seamless tubes and pipe, rivets, bolts, nuts, screws, etc.

11. *Can Ticon iron be heat treated?*

After fire or cold working the structure is improved by annealing or normalizing. As it contains little carbon, Ticon iron cannot be appreciably hardened by any heat treating operation.

12. *What is the proper annealing temperature and what effects are produced?*

The proper annealing temperature is 1100 to 1250° F., resulting in more ductile, uniform working qualities.

13. *What is the proper temperature for normalizing and what effects are produced?*

The proper normalizing temperature is 1700° F., followed by cooling in air. Effects produced are the refinement of grain and improvement of physical properties.

14. *Can Toncan Iron be hot worked?*

Toncan Iron can be hot worked, flanged, forged, rolled or upset above 1,950 degrees Fahrenheit and below 1,550 degrees Fahrenheit. The iron will stand more work and distortion in the lower temperature ranges than steel.

15. *Can Toncan Iron be cold worked?*

Yes, it is softer and more easily worked than other ferrous products.

16. *What is the effect of cold working on Toncan Iron's corrosion-resistance?*

Practically none. In this respect, Toncan Iron differs materially from all other comparable ferrous metals, in which corrosion-resistance is lessened by cold working.

17. *What are the machining qualities of Toncan Iron?*

Toncan machines much the same as dead soft steel, so that best results will be attained if certain precautions are followed. It is important that cutting tools have small lip rake and ample clearance so chips will not clog. The use of a sulphated base cutting oil is desirable. In drilling, use shackle ball drill with flutes running at sharper angle than usual. The point of the drill should be as flat as possible.

18. *What are the heat-resisting qualities of Toncan Iron?*

Toncan Iron resists scaling better than ordinary steel. It is recommended for service up to 800° F.

19. *What are the acid-resisting qualities of Toncan Iron?*

Toncan Iron shows far superior resistance to the attacks of dilute sulphuric, hydrochloric and other acids than do steel, wrought iron, copper-bearing steel or any similar ferrous metal.

20. *What are the general corrosion-resisting qualities of Toncan Iron?*

On exposure to atmospheric conditions, Toncan Iron exhibits a much slower rate of solution and oxidation or rusting than any other ferrous metal. This has been conclusively demonstrated by installations still in good condition after many years' service. Toncan also has shown its superiority to other iron and to steel in the exacting service of the petroleum industry, and locomotive boiler tubes made of Toncan are shown by actual service to be far superior to steel, charcoal or puddled iron.

21. *What are its wear or abrasion-resisting qualities?*

In general, the abrasion-resistance of Toncan Iron is similar to that of low carbon steel. However, abrasion-resistance depends upon the nature of the service demanded, so no broad conclusions can be established.

22. *Can Toncan Iron be galvanized?*

As heavy and tightly adherent a coating of zinc can be applied to Toncan Iron as to any other ferrous material. Galvanized Toncan Iron sheets in commercial sizes and gauges are regularly furnished.

Toncan Iron is also made in Galvannealed, Oven Lining (Burnished galvannealed), Tin-coated and Terne-coated finishes.

IRON AND STEEL METALLURGY

*Definitions of Terms and Processes
Common to the Industry*

—Courtesy of Steel and Metal Topics

- Iron Ore**—Contains Iron and Oxygen and impurities. Smelted in Blast Furnace, removing Oxygen and part of impurities and adding Carbon, makes **Pig Iron**
- Pig Iron**—Is poured into mold making **Pigs**
- Foundry Pig Iron**—Melted in Cupola and cast makes **Iron Castings**
- Malleable Pig Iron**—Melted, cast and heated in Scale, makes **Malleable Castings**
- Grey Forge Pig Iron**—Melted in a Puddling Furnace, then rolled, squeezed and rolled, makes **Muck Bar**
- Muck Bar**—Or Wrought Scrap cast into short lengths, piled, heated and rolled, makes **Wrought Iron**
- Muck Bar**—Treated as above and rolled into strips, makes **Skelp Iron**
- Skelp Iron**—Bent into the shape of tubes and welded, makes **Iron Pipe**
- Muck Bar**—Or Steel melted in a Crucible with Charcoal, makes **Carbon Steel, Tool Steel or Crucible Steel**
- Bessemer Pig Iron**—Draws Iron Blast Furnace or melted in Cupola, poured into Converter, with air blown through it to burn out the impurities makes **Bessemer Steel**
- Pig Iron**—Melted, or in pig, with or without Scrap, when poured in Open Hearth Furnace makes **Open Hearth Steel**
- Low Phos. Pig Iron**—Treated as above in an acid (Silica or lime) lined furnace makes **Acid O. H. Steel**
- Basic Pig Iron**—Treated as above in a basic (Dolomite) lined furnace to remove Phosphorus makes **Basic O. H. Steel**

Alloyed Iron—The product of carefully selected raw materials and pig iron refined in a Basic Open Hearth furnace to a point where the impurities are reduced to the practicable minimum, after which copper and molybdenum are added in correct proportions, is

Toncan Copper Molybdenum Iron

- Ingots**—Are rolled into _____ **Blooms or Billets**
- Ingots**—Are rolled into _____ **Slabs**
- Blooms**—Are rolled into _____ **Rails**
- Blooms**—Are rolled into _____ **Structural Shapes**
- Slabs**—Are rolled into _____ **Plates**
- Billets**—Are rolled into _____ **Bars and small shapes**
- Billets**—Are rolled into _____ **Steel Skelp**
- Billets**—Are pierced, rolled and drawn through dies, making _____ **Seamless Tubes**
- Billets**—Are rolled into _____ **Rods**
- Steel Skelp**—Bent into the shape of tubes and welded, makes _____ **Steel Pipe**
- Steel Skelp**—Cold formed into the perfect shape of tubes and electric resistance welded into **Republic Electric Weld Pipe**
- Rods**—Are drawn through dies into _____ **Wire**
- Rods**—Are headed into _____ **Rivets and Bolts**
- Rods**—Are welded into _____ **Chain**
- Wire**—Is made into _____ **Nails and Fencing**
- Ingots**—Are rolled into _____ **Sheet Bars**
- Sheet Bars**—Are rolled into _____ **Black Sheets**
- Black Sheets**—Cleaned, cold rolled and coated with Tin make _____ **Tin Plate**
- Black Sheets**—Cleaned, cold rolled and coated with lead and tin make _____ **Terne Plate**
- Black Sheets**—Cleaned, cold rolled and coated with Spelter (Zinc) make _____ **Galvanized Sheets**
- Black Sheets**—Galvanized and annealed, make _____ **Galvannealed Sheets**
- All Sheets**—Can be stamped into _____ **Various Forms**

GAUGES AND SIZES OF TONCAN SHEETS

BY ACT of Congress March 3, 1893, U. S. Standard gauges for black sheets were established as given in the table on the next page.

Toncan iron sheets run true to gauge with only the customary, slight, allowable variation which cannot be avoided in the best mill practice. Galvanized sheets are slightly heavier than black sheets of the same gauge, as will be noted in the weights given in the table.

All Toncan iron galvanized sheets are clearly marked with the gauge number. This safeguards everyone concerned against mistake or substitution of a lighter gauge for the gauge specified.

Toncan iron is not made lighter than 26-gauge black and 28-gauge galvanized.

Specifications should always indicate gauge by number as no one gauge is generally regarded as "standard" for any use or product.

The added cost of heavier gauges is usually more than justified by the added value and the assurance of longer service, while the added strength is also desirable in many uses.

28 gauge Toncan iron is widely used for eaves trough, conductor pipe, ridge roll, flashing, gutter and similar work.

The use of 28 gauge for these services, however, is very common and it is to be preferred always, while 24-gauge is also being used to a considerable extent for extra service, especially in valley, flashing and other installations where repairs or replacement are more difficult.

For roofing, siding, etc., nearly all of the gauges are used. 24 or 26-gauge is usually preferred for residences, churches, stores, barns and similar buildings, while for shops, railway and mine buildings and other structures where corrosive conditions are severe, 18, 20 or 22-gauge is usually specified.

For special uses a careful study of strength and service requirements will indicate the proper weight to use. For example, in galvanized corrugated culverts gauges 8 to 16 are used, depending on the size of the culvert.

Iron and Steel Sheet Gauge Tables

No. of Gauge	BLACK Adopted by U. S. Government, July, 1893			GALVANIZED	
	Weight per square foot in pounds Avoirdupois	Approx. Thickness		Weight per square foot Avoirdupois	
		In Fractions of an inch	In Decimal Parts of an inch	In Ozs.	In Lbs.
3	10	1-4	.25		
4	9.375	15-64	.234375		
5	8.75	7-32	.21875		
6	8.125	13-64	.203125		
7	7.5	3-16	.1875		
8	6.875	11-64	.171875		
9	6.25	5-32	.15625		
10	5.625	9-64	.140625	92½	5.781
11	5.	1-8	.125	82½	5.156
12	4.375	7-64	.109375	72½	4.531
13	3.75	3-32	.09375	62½	3.906
14	3.125	5-64	.078125	52½	3.281
15	2.8125	9-128	.0703125	47½	2.969
16	2.5	1-16	.0625	42½	2.656
17	2.25	9-160	.05625	38½	2.406
18	2.	1-20	.05	34½	2.156
19	1.75	7-160	.04375	30½	1.906
20	1.50	3-80	.0375	26½	1.656
21	1.375	11-320	.034375	24½	1.531
22	1.25	1-32	.03125	22½	1.406
23	1.125	9-320	.028125	20½	1.281
24	1.	1-40	.025	18½	1.156
25	.875	7-320	.021875	16½	1.031
26	.75	3-160	.01875	14½	.9062
27	.6875	11-640	.0171875	13½	.8437
28	.625	1-64	.015625	12½	.7812
29	.5625	9-640	.0140625	11½	.7187
30	.5	1-80	.0125	10½	.6562
31	.4375	7-640	.0109375		
32	.40625	13-1280	.0101562		
33	.375	3-320	.009375		
34	.34375	11-1280	.00859373		
35	.3125	5-640	.0078125		
36	.28125	9-1280	.00703125		
37	.265625	17-2560	.006640625		
38	.25	1-160	.00625		

Commercial practice permits of a tonnage weight variation of 2½% either way on gauges 23 to 30 inclusive. 3½% either way on gauges 17 to 22 inclusive and 5% either way on gauges 16 and heavier as produced by Sheet or Jobbing Mills. Percentage variation is not applicable to thickness.



REPUBLIC STEEL
C O R P O R A T I O N
GENERAL OFFICES - YOUNGSTOWN, OHIO